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EDITED BY J. McKEEN CATTELL

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OCTOBER, 1930

THE WAYS OF MAN, APES AND FISHES

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THE ways of man are devious and perplexing. Why, then, add to our perplexities by dragging in the ways of apes and fishes? It is with the hope, at least, that a larger picture of life would give us some inkling of where man came from and where he is going. And besides, to visualize the coming and going of man, we needs must have other actors in the picture for measurement and comparison.

In the vast perspectives we have in mind, the minor deviations from the standards of behavior disappear and the great highways of animal life stand out with amazing clearness as supplementary explanations of one another. Mammals, birds, reptiles, fishes, sea-scorpions and many others are the great constellations of animal life. They are our fellow travelers along the Milky Way of the biological heavens, and it is only by their beacon lights and trailing orbits that we can plot the curve of man's ascent.

Too many lights confuse us and defeat their purpose. It is well for us, therefore, that our guiding stars are far apart and far away. But on the other hand, it inevitably follows that there are more missing links in our starry chains of evidence than real ones. That is, the unknowable blanks in all our plotted curves of evolution are much greater than the dot-like sparks of evidence which roughly, but surely, indicate the evolutionary course of events. The biologist bridges the minor gaps on the assumption that developmental changes, once initiated, tend to carry on in their predetermined directions. The major ones may call for supplementary interpretations that differ with different interpreters.

The widest gap, or the so-called "missing link" in the evolution of animal life, is not between man and the apes. Far from it. From man to his nearest apelike kindred and far beyond them down to the fishes, the main line of animal evolution is clearly indicated by a chain of evidence so closely linked that no zoologist is inclined to question it. But between the fishlike vertebrates and the invertebrates comes the widest and most perplexing gap in the whole animal kingdom. It separates the genetic tree of animal life into two great divisions, an upper and a lower, that stand on widely different levels of bodily organization. The events that bridged this great gap—joining high road to low road, or uniting the root, stem and flower of life into a continuous series of genetic developments—were no doubt of profound significance.

These two problems—the genetic relation of man to apes, and vertebrates to invertebrates—are to-day among the outstanding problems of animal evolution. In some respects they are much

alike. Both problems touch the foundations of all the biological sciences and have a direct bearing on the problems of every-day life.

The brilliant discoveries of the last generation or so have greatly changed the mental attitude of the biologist towards evolution and have raised many new problems to perplex him. But his main conclusion as to the reality of evolution and the origin of man remains as it was in Darwin's time. In plain language, biologists regard man as a special kind of ape, a very distinguished ape, to be sure, but nevertheless an ape and the offspring of apes whose ancestors, in the days of their prime, were some sort of primitive monkeys. And still farther back they were some sort of reptiles, amphibians, fishes and so on to still more primitive forms. As far as our vision reaches, this genetic sequence of forebears and offspring goes on for untold millions of years without any radical change in the method of producing them. It is not evolution, therefore, but the *method* of evolution which now chiefly concerns us. Evolution itself has long since passed out of the field of scientific controversy. There is no other subject on which scientific opinion is so completely unanimous. It is the one great truth we most surely know.

We shall try to show, very briefly, that this evolutionary method is a definite, irreversible process of creation, cosmic in extent, logical in all its causal sequences and with distinctly moral and ethical qualities of its own. It is righteous because, on the whole, it is creative, preparatory, self-sustaining and vital. All living and non-living things were apparently created in this logical or natural way, and all of them must act, or behave, in accordance with its moral and ethical principles. Under its compulsion, man has always tried, consciously or unconsciously, to imitate this fruitful process, and thereby has made his own vital profits. In this way arose within him a wavering image of realities, or a crudely corresponding system of logical activities, mental and bodily, which permeate and motivate all phases of his art, science and religion. And as man's vision of realities clarified, he was summoned to new endeavor and shown new ways to realize old ideals.

We have tried to illustrate in Figs. 1 and 2 the evolution of the principal kinds of human beings and other animals in a way that roughly indicates: (1) their rise and decline in geologic time; (2) the genetic relations of the great branches of animal life to one another, and (3) the relative amount of their upward progress. Some of the external characteristics of man and his nearer relatives are shown, rather than the less familiar anatomical structures on which they are based.

One of the chief factors that predetermines the bodily structure of any animal is the germinal material it has received as a heritage from its ancestors. Each natural group has a peculiar kind of germ-plasm of its own that gives continuity to the group and a recognizable similarity of structure to all its members. Thus the germ-plasm peculiar to all the great classes and orders has an extraordinary stability, or the power to reproduce itself, over and over again, for countless generations. These waves of reproductive power ultimately break on the shores of time and are visibly expressed in countless varieties of living forms, all under the bondage of their peculiar heritages (indicated in Fig. 1 by wave-like dotted lines).

But these genetic impulses can not be propagated in a vacuum. They live and grow in the fertile soil of their environmental opportunities. And as they grow, they create the more intimate environments of associated bodily parts and the wider environmental circles of associated individuals, all acting and re-

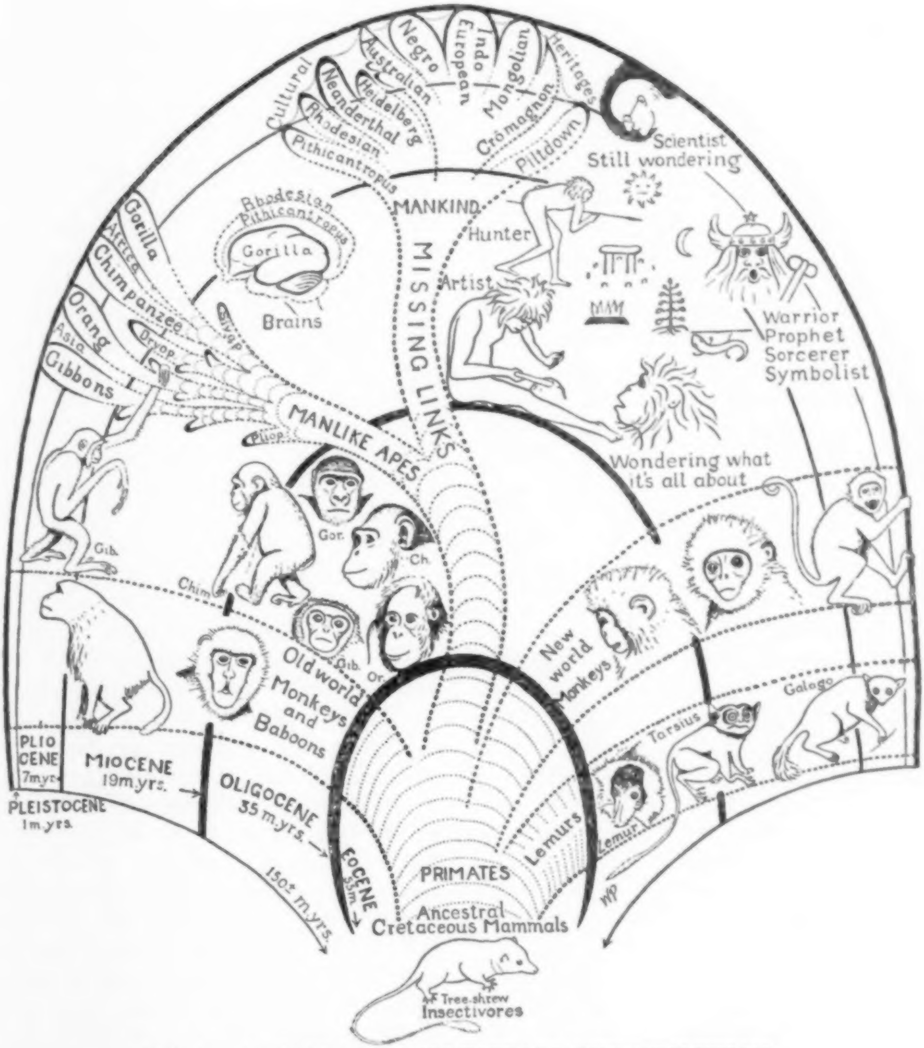

FIG. 1. A DIAGRAM TO ILLUSTRATE THE EVOLUTION OF MANKIND AND HIS NEARER RELATIVES. THE SYMBOLS OF THE GREAT CREATIVE PROCESS WHICH PLAYED SUCH AN IMPORTANT PART IN THE EVOLUTION OF MAN'S MENTAL IMAGERY, SUCH AS THE SUN, MOON, FIRE, WATER, MAGIC TREES, TOMBS AND DRAGONS, ARE ROUGHLY INDICATED.

acting on one another in the common business of growth and self-perpetuation. Thus the incidental opening or closing of a functional bodily door, a vocalized sex call, a germinating "idea" with its accompanying gestures, as well as the more obvious fluctuations of supply and demand, are cooperative causal factors in the evolution of life.

Laboratory experiments and measurements, however accurate or often repeated, are of comparatively little assistance in estimating the creative value of any one of these multitudinous factors. Our dominant faith to-day, as it always has been, is based on the perception of major results, *after* they have been produced in nature's laboratory.

Thus, to keep his head above the floods of watery details that threaten to engulf him, the biologist must apply the principles of birth control to his own activities. He will defeat his own purpose if, through lack of perspective, he fails to perceive the major products of nature and the trend of the great currents of evolution, for they constitute his most reliable standards of reference.

Candid self-inspection, from time to time, will also be helpful. Our present conclusion as to the origin of man has been reached only after a long series of cocksure assertions and more or less apologetic retractions. It is now based about as much on the reconsideration of old evidence, long since available, as on the impressiveness of the new. Our reformed mental attitude, as a requisite expiation for past sins, may be too obviously overdone. It is too often coupled with an ostentatious display of scientific precaution, and an undue exaggeration of petty details. On the other hand, the attempts to explain these details may fall far below the usual standards of scientific criticism.

This fickleness in judgment, individually and collectively, is about as characteristic of biologists as it is of other kinds of human beings, as the history of scientific opinion, especially in regard to the origin of man and the origin of vertebrates, so clearly demonstrates. In fact, the biologist, like all the rest of us, is at heart a hard-boiled fundamentalist and a dogmatic propagandist, as indeed he should be, if he has any convictions that are worth propagating. He is incredibly blind to the most obvious facts, if they do not fit into his peculiar philosophy. Then, perhaps, he may see a new light, and like the traditional unbeliever he is suddenly converted to a new dogma.

It now appears that man is far older, perhaps many millions of years older, than any biologist has dared to assume. What were these first men like? Where did they come from? How did they get that way? What a vast time-space theater for human development! How many causal factors for conjecture! How little we really know about them!

Shall we call the "first" man a dawn-man? That name, no doubt, is less irritating to the Biblical fundamentalist than ape-man, but it is not very significant to the biological fundamentalist. Every step in evolution is the dawn of a new day, and every man is a dawn-man to future generations. Of all open places on this earth, five, ten or twenty million years ago, was a plateau in central Asia the only campus available for the development of man? It may be. But we never felt very sure about the geographical location of the Garden of Eden, nor just what its ecological opportunities and restrictions were. Was the dawn-man a tree climber, a timid top-floor boarder in damp and gloomy forest chambers? The two-o'clock-in-the-morning dawn-man undoubtedly was. But how about the dawn-man that arose somewhat later in the morning? Was he a born hunter, driven by an overpowering "ambition" into the great open spaces of the sunlit, windswept uplands? Very likely. But what was his ambition, anyway? Was it the same ambition that drove the hunting worm to seek a better living in the fertile belly of a higher animal? Was the equally commendable ambition of the go-getter worm and the go-getter ape rewarded in the same way? As for climbing *versus* running, swimming or flying for a profession, we could hardly expect a hundred and fifty pound ape, or thereabouts, to make a worth-while living flitting from tree to tree like a monkey or a bee. The defects of his superiority would automatically restrict his freedom to the ground.

Such speculations, though justifiable as a crude outlining of possibilities, are

rather futile and should not be taken too seriously. The main fact remains that the deeper we delve into the geologic history of man the more kinds of human beings we find scattered here and there throughout the better known regions of Europe, Asia and Africa. And the older they are, the more they resemble, on the whole, the type of beings we call apes. There was, no doubt, a great variety of bodily and mental aptitudes among the many kinds of man-like apes and ape-like men. What those minor details were, we do not know. But we do know that in the whole gamut of animal life there are no hands, feet, skulls and faces, no brains, no mental and bodily aptitudes, no records of embryonic and geologic developments, taken in the altogether, so much like our own as those of apes.

In all this there is nothing very startling or essentially new from an evolutionary standpoint. It is all in harmony with the Darwinian concept of the origin of man.

When we plot the course of animal evolution on a larger scale we find that all the genetic trails converge towards one great highway of life that takes us ever downward from man to primitive apes, and from there to monkeys, down to lemurs, and far beyond them to other arboreal mammals resembling the tree shrews. And then, over steeper terraces, the way descends to still lower levels, to reptilian, amphibian and fishlike prototypes.

There are no unaccountable embryological or anatomical gaps, nor any notable inconsistencies in the geologic records of this long genetic series as we trace it downward through many hundred million years. From mankind to fishes they are all vertebrate animals and all of them have the same elaborate sets of organs, arranged in the body in peculiar groups and subgroups in accordance with the same architectural plan.

When we study this enormous genetic series from man to fishes, the amazing fact is brought home to us that underneath the protean mask of countless adaptive adjustments and readjustments of bodily parts and organs to one another, the basic plan that makes them all alike never changes. It is evident, therefore, that during these hundreds of million years, all the combinations of germ-plasm in sexual reproduction, and all the variations in environments, could neither alter nor repress the fundamental potentialities of this structural plan.

There are no units of physical power by which we can measure or express those creative potentialities. And when we survey the actual unfolding of those potentialities, each upward step, as in a developing embryo, a preparation for the next; when we trace the perfectly logical series of adjustments that are made to meet the new demands of growth and to utilize its newly acquired freedom—all these cumulative results indicate a predetermined course of events, and something that is very much like a predetermined purpose. And that purpose can be rightly estimated only in terms of its own products.

Among the more notable improvements that raise the bodily powers to higher levels are the transformation of fins into legs, the substitution of lungs for gills, the addition of one chamber after another to the heart, various devices for sorting and distributing the blood and regulating the temperature of the body and innumerable inventions that better insure reproduction and make better provisions for the young and immature. In brief, they are just the sort of improvements in the give and take of vital traffic that must be made from time to time in a thriving city, if it is to go on living and growing.

The utility of such innovations is the measure of their creative value. As in

human history, such inventions, no matter how they are initiated, produce the great upward surges in the progress of life. They punctuate its history into eras and periods, and divide life into many different kinds of living things, each one on a different level of attainment, each one with different and unknowable potentialities.

Beyond the fish stage comes the widest gap in the whole animal kingdom. The differences between man and any other vertebrate are comparatively minor differences in a common structural plan. But the vertebrates and invertebrates seem to be built on fundamentally different plans. However, this difference is more apparent than real, as we have fully explained elsewhere.[1] Recent discoveries concerning the very ancient Ostracoderms, some of them as yet unpublished, in many ways confirm that explanation.

For a century or more, this subject has been a storm center of controversy among zoologists. It has been one of those strange battlefields where many issues were involved and where many gallant partisans of one view or another were firmly entrenched in old traditions. They attacked and counterattacked with dogmatic fury, but rarely with any notable effect. Meantime they calmly ignored one another. Here the innate fundamentalism of the scientific anthropoid was shown at its best and its worst. This is not a lament nor a claim for immunity. It is an explanatory field note on the ways of mice and men by a participant in the controversy for more than forty years.

Typical vertebrates make their first appearance in the Devonian age as highly developed fishes that are essentially the same as those alive to-day. But it is evident that they really did come into existence at a very much earlier period.

With them are found the fossil remains of many other kinds of animals of very great antiquity. Two kinds are of special interest in this connection. One of them is a sort of "dawn-fish," if you please, called Ostracoderms. They once formed a great class of animals, and until recent years very little was known about them. The other kind are the giant sea-scorpions which for many millions of years had been the most active and highly organized invertebrates of their time. The sea-scorpions, although themselves long since extinct, have left many collateral descendants that are alive to-day, such as the little land scorpions, spiders and the so-called horseshoe crab, or Limulus. They constitute a special group of Arthropods called Arachnids.

Now we find, underneath a mask of confusing superficial details, that the basic structural plan of the Arachnids is the same as that of fishes, reptiles, apes and man. Furthermore, nothing like it is found anywhere else in the whole animal kingdom.

This structural plan, omitting technicalities, is a very intricate picture puzzle, or anatomical pattern, made up of nerves, sense organs, jaws, gills, heart, brain, endocranium, notochord and alimentary organs, so as to form definite groups of organs and bodily regions, each group consisting of a definite number of similar parts and functions, and all arranged in a definite sequence (see Fig. 3).

The agreement in so many fundamental peculiarities between the picture puzzle patterns of sea-scorpions and fishes is so complete that it practically excludes the possibility of a meaningless coincidence. Its significance is obvious. The conclusion is forced upon us that the main ancestral line of man extends far beyond the fishes, through the Ostracoderms, the sea-scorpions and their arthropod ancestors. And from these

[1] William Patten, "The Evolution of the Vertebrates and their Kin," P. Blakiston, 1912.

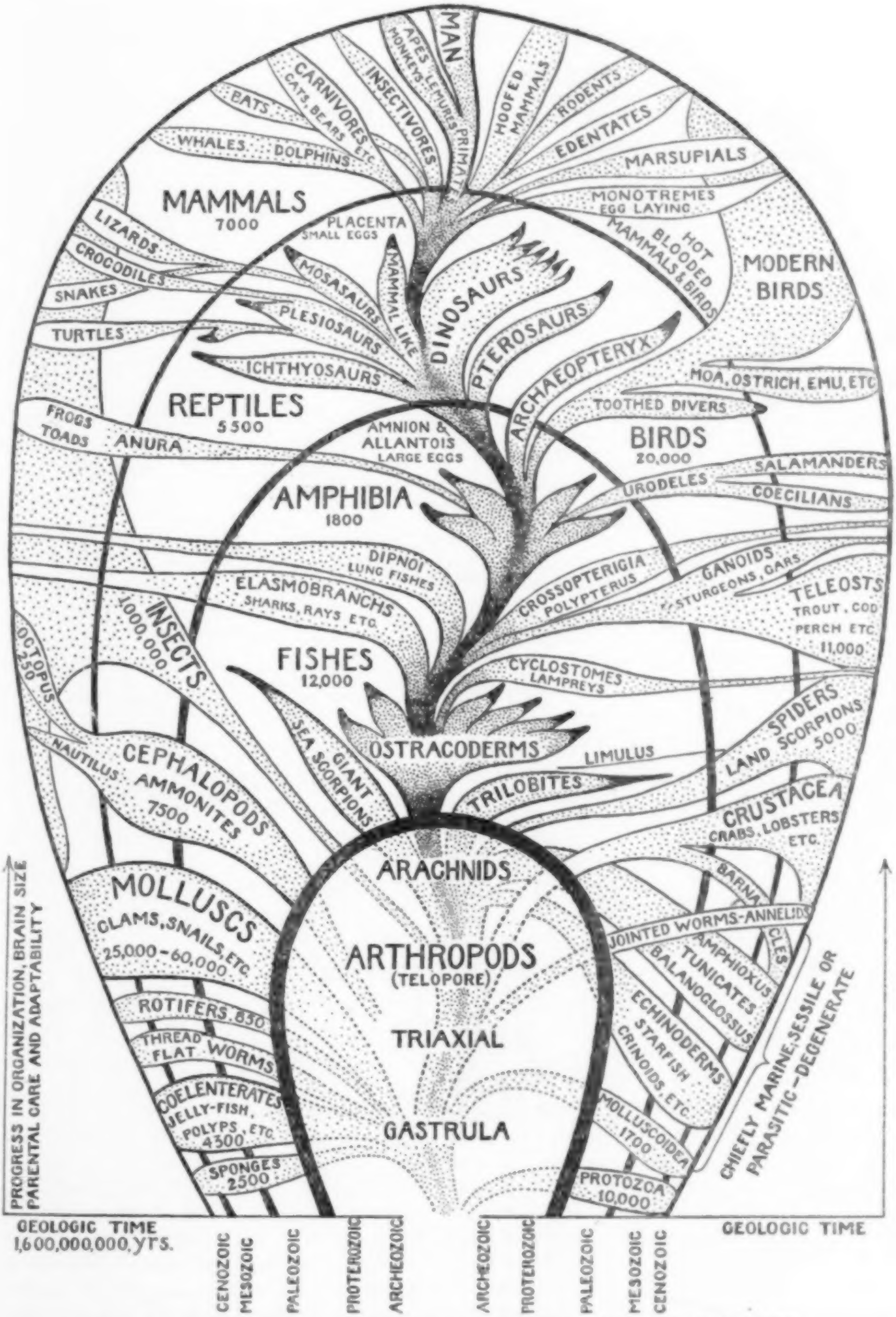

FIG. 2. A DIAGRAM TO ILLUSTRATE THE RISE AND DECLINE OF ALL THE GREAT CLASSES OF ANIMAL LIFE. EACH ANCESTRAL CLASS WAS ONCE A LEADING TYPE, THE APEX, HEAD AND FRONT OF THE SOCIAL LIFE OF ITS TIME. MAN CAME ON HIS METEORIC CAREER TRAILING CLOUDS OF RADIANT LIFE WHICH ENVELOPED AND SUSTAINED HIM ON HIS WAY.

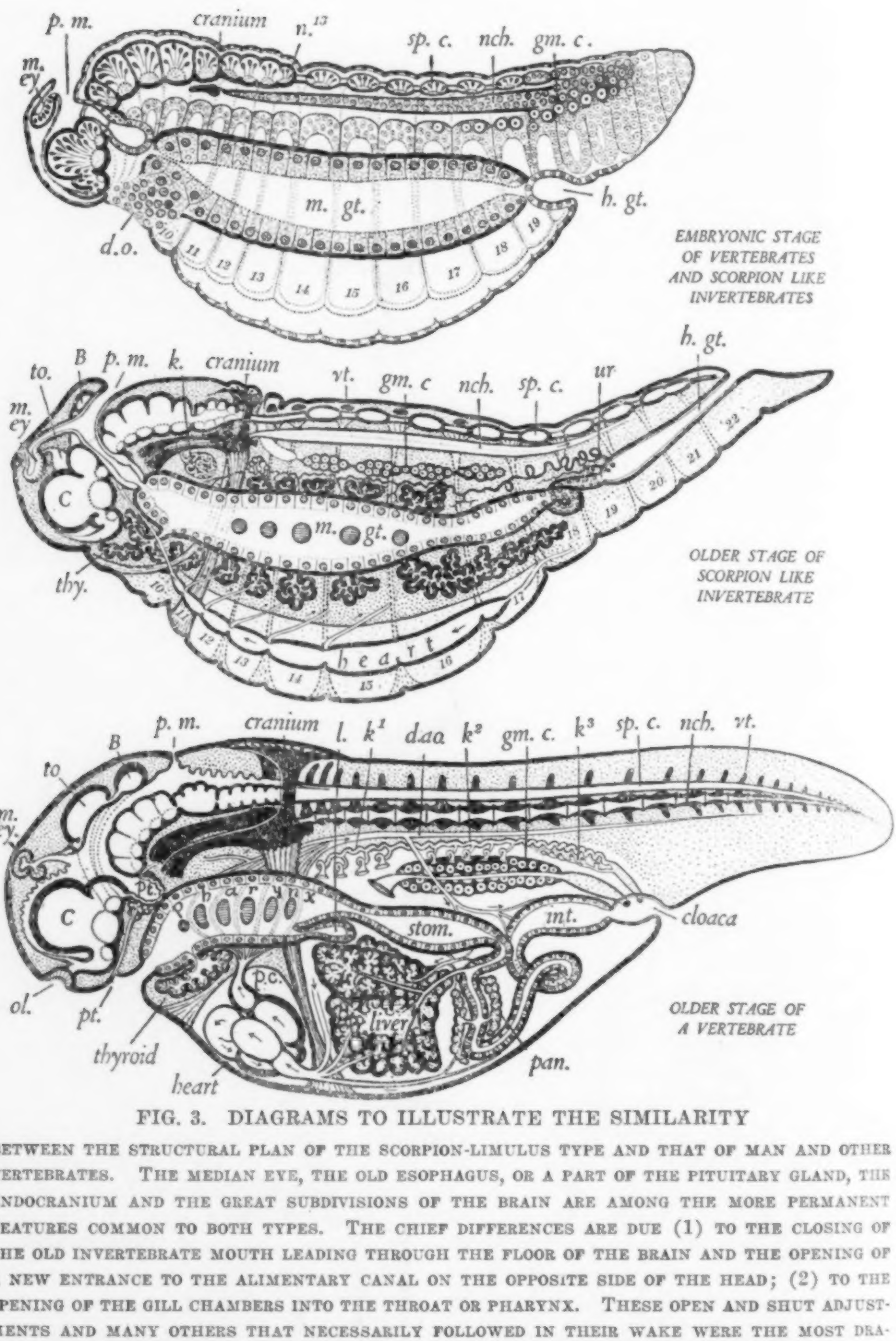

FIG. 3. DIAGRAMS TO ILLUSTRATE THE SIMILARITY

BETWEEN THE STRUCTURAL PLAN OF THE SCORPION-LIMULUS TYPE AND THAT OF MAN AND OTHER VERTEBRATES. THE MEDIAN EYE, THE OLD ESOPHAGUS, OR A PART OF THE PITUITARY GLAND, THE ENDOCRANIUM AND THE GREAT SUBDIVISIONS OF THE BRAIN ARE AMONG THE MORE PERMANENT FEATURES COMMON TO BOTH TYPES. THE CHIEF DIFFERENCES ARE DUE (1) TO THE CLOSING OF THE OLD INVERTEBRATE MOUTH LEADING THROUGH THE FLOOR OF THE BRAIN AND THE OPENING OF A NEW ENTRANCE TO THE ALIMENTARY CANAL ON THE OPPOSITE SIDE OF THE HEAD; (2) TO THE OPENING OF THE GILL CHAMBERS INTO THE THROAT OR PHARYNX. THESE OPEN AND SHUT ADJUSTMENTS AND MANY OTHERS THAT NECESSARILY FOLLOWED IN THEIR WAKE WERE THE MOST DRAMATIC AND FRUITFUL INNOVATIONS IN THE WHOLE HISTORY OF ORGANIC EVOLUTION. THEY LIBERATED THE POTENTIALITIES OF THIS STRUCTURAL PLAN AND PRODUCED THE GREAT UPWARD SURGE WHICH IN HISTORIC PERSPECTIVE APPARENTLY SEPARATES THE FISHLIKE ANCESTORS OF MAN FROM THEIR ARACHNID-LIKE PREDECESSORS.

the way is fairly clear to the jellyfish and the protozoa (see Fig. 2).

It will be seen that each of these ancestral classes was once a leading type, the apex, head and front of the advancing social life of its time. Thus man came on his meteoric career, trailing clouds of radiant life which enveloped and sustained him on his way.

This larger and clearer perspective of the evolution of man, covering something like a thousand million years, in all sorts of physical and social environments, is of profound significance, not because sea-scorpions are more respectable ancestors than the mud-worms worshiped by the biologists of a generation ago, but because, knowing so much more of the orbit of man's ascent, we may better understand the laws that governed his progress. There is no other series of causal phenomena of equal extent that is so precisely predetermined in its inception, in the course it follows and in the creative fertility of its results. There is no other great series of phenomena known to science where the moral and ethical principles of evolution are so apparent in the performance, and where their application to human affairs is so obvious.

The four outstanding betterments in this upward progress of animal life were as follows.

(1) The upbuilding of bodily powers in each individual on its initial foundations. These processes are all of the same character and all move toward the same objective. That is, they are various economic betterments in the give and take of vital metabolism which serve to enlarge the scope of life. For example, the increase or decrease of local bodily production; the opening of more direct lines of communication, or the enlargement of transporting channels for the exchange of vital commodities to meet the new demands of bodily growth. In short, any betterment in the mutual service of the bodily parts and organs which better insures the welfare of the body as a whole and gives further vent to its latent potentialities.

(2) Heredity and parental provision. This includes all those betterments in the duplex machinery of sex whereby the accumulating profits, or heritages of life, are redistributed, renovated and conserved. It also includes all those betterments in parental shelters, in parental foraging and guidance, whereby maturity gives itself up to immaturity. Here the universal altruism of life, the secret preparation for anticipated emergencies and the sacrificial usage of all the highest faculties of life for the tender germs of life are most apparent.

(3) Social betterments. This includes all those betterments in the give and take of social commodities, or the destructive usage of one another's powers for recreative purposes. All such betterments tend to strengthen the functional bonds that unify and sustain the social life of plants and animals the world over. They tend to conserve rather than utterly destroy the more useful types of individual life. Here the real purpose of death, or the destructive side of life, is most apparent.

(4) Brains and mentality. All these bodily betterments depend on the coöperative nervous unity of bodily parts and organs with one another and with the activities of the external world. They are all registered in some way in the texture of the central nervous system. Hence the increasing volume and complexity of the brain is the clearest index we have of all these evolutionary betterments in nature's art of living and dying. It is the one visible agency that coordinates all phases of internal life and responsively adjusts them to the activities of the outer world.

Thus animal life advances on a very broad front, where the smallest particle, organ, individual or social group may be

a leading creative factor. The most striking advances are in bodily powers, in germinal, parental and social provisions for posterity, and in the relative volume of the brain.

As we have indicated elsewhere,[2] there is an unchanging method in all these cosmic and organic adjustments that has a distinctly moral and ethical quality. That is, over all the phases of growth and evolution there is a compelling directive discipline with ample freedom for profitable individual variation; an overpowering predetermination in the "nature of things," but with many fertile opportunities for adaptive readjustments, or for getting in right again with the new conditions created by growth and evolution. This process of adaptation, or this getting into more fruitful relations with the world at large, is the biologist's name for righteousness.

In the unavoidably mongrel metaphor of mechanism and vitalism, matter and spirit, nature virtually says to every individual thing, dead or alive: Thou shalt. Thou shalt not. Thou mayst. Be mutually serviceable or be destroyed. Sacrifice lesser values by rightly using them to make greater and more enduring values. Self-sacrifice by the right usage of individual powers for the common welfare is the source of all those enduring profits, or heritages, on which evolution depends. Evolution, therefore, is the cosmic yardstick of all these basic moral and ethical virtues, and the only authentic revelation of their creative values.

Good and evil are inseparable factors in this method of creation. They are but other names: (1) for the various processes of destruction, reconstruction and innovation in cosmic and organic metabolism; and (2) for all those maladjustments produced by growth of any particular kind, and the adaptive readjustments that are requisite for existence under the new conditions so produced. All these factors are essential to the continuity and progress of cosmic and organic life.

Man ultimately came into being as the ripening product of this compelling predetermined order, chemical, terrestrial, organic and social. It matters little when or whence he came, or what was the color of his skin or the shape and thickness of his skull, compared with the fact that his whole structure and behavior were the visible expressions of a cosmic creative method that will suffer no other method to endure.

When first we see him, man was fully erect and distinctly different from all his predecessors in that he was provided with three highly cooperative betterments for the larger give and take of social life: (1) hands specially fitted for the making, distribution and exchange of detachable personal properties; (2) articulate speech for the transmission and exchange of personal experiences, knowledge or ideas, and (3) more "brains," far better adapted than ever before to perceive and utilize the larger ways and means of living.

The foundations of all these complex organs of transmission and reception, such as hands, tongue, larynx, ears, eyes and brains, were laid down in their present anatomical relations hundreds of millions of years beforehand in the fishes or even in still more primitive forms.

Thus, with the advent of man, new kinds of social tissues and social functions arose which formed a new system of social metabolism, with new opportunities for adaptation and for profitable variation and conservation. In fact, it was the advent of a new kind of heredity and the initiation of new kinds of heritages.

This new phase of life stands on a far higher level than ever before. It differs more widely from the old life, in its po-

[2] W. Patten, "The Grand Strategy of Evolution," R. Badger, 1920.

tentialities at least, than apes do from fishes. It has produced, in a relatively short time, a greater revolution in the art of living, a greater change in the complexion of terrestrial life, than any other known organic innovation.

Apes, reptiles and fishes, for example, are perpetuated by means of special kinds of germ-plasm. Each one of these groups of animals advances on a common front under the bondage of similar germinal heritages. With mankind it is different. All the different genera, species and varieties of mankind, in addition to their common germinal heritages, have this new system of cultural heritages by means of which the profits of individual lives are eventually redistributed, communized, socially assimilated and regenerated in an endless variety of new forms.

These new cultural factors are largely external and quite distinct from the germinal factors in sexual reproduction. Nevertheless they greatly enlarge the scope of heredity. They help to renovate and perpetuate the social life of mankind, as a whole, in much the same way that the living germ-plasm helps to renovate and perpetuate the life of individual organisms.

Thus all kinds of human beings are functionally unified by their cultural as well as their germinal heritages. They advance, ameba-like, on a wavering front to higher levels. Each individual, under the bondage of his germinal and cultural heritages, is a debtor and a creditor, a creator of, and himself created by, the system of realities of which he is a living part.

No man can change or escape from this basic method of life and growth. Man himself is a miniature expression of it, and can do his creative work in no other way.

And so primitive man, dimly perceiving the provisioning artistry in the activities of a mother-like nature, began some millions of years ago to wonder what it was all about. Unwittingly imitating the alluring model always before him, he also became an artist and an anticipating provider, an ever hopeful visionary, always seeking, with his clearing vision of realities and his augmenting powers, for still larger ways and means of living.

With infantile simplicity, he artfully tried to check or stimulate the activities of his natural mother. He made crude pictures of nature's familiar products, mocked them, threatened them with disaster or summoned them with childish gifts, with wailings and gesticulations, to do what he most desired. Then, confusing fiction with reality, he naïvely tried to substitute his totems, amulets and other symbolic toys for the cosmic powers they represented, hoping thereby to capture the unattainable.

By this experimental monkeying with the chains that bound him, the scientific ape-man became a magician, sorcerer and medicine-man, a clever juggler with materialistic symbols, a befuddled mystic misled by the glimmerings of an immature imagination, vainly seeking to find an effortless way to reproduce the creative miracles of nature or to escape from the bondage of causal realities. The hard-boiled scientist who to-day dreams of creating life in a test-tube is one of the surviving types of befuddled medicine-men.

Believing that he had finally discovered the secret of creation, he proclaimed himself a god, and as a warrior, prophet or king sought to conquer the world for himself and his next of kin. But man was slowly learning, oh, so very slowly learning, that he could not get what he wanted in that way. A better imitation of the creative way, a better matching of human logic with nature's logic was requisite.

He was slowly learning that he could never conquer nature. Nature always

conquered him. He was learning that to win, he must first submit, or adapt his ways to her ways by the conquest of himself. For many thousands of years, thoughtful men the world over, under the pseudonym of religion, were unconsciously recognizing the moral and ethical principles of evolution—such as the necessity for hard labor, self-sacrifice, mutual service, righteousness and provision for the future—and were building these basic virtues into the foundations of their science and art of living and dying.

With the clearer recognition of these creative methods, and a better application of them, the era of sorcery is slowly giving way to the era of scientific maturity.

The spirit of science is the spirit of evolution visibly expressed in the life and growth of mankind. The ideal scientist—never an actuality, even though every living thing is in some respects a scientist—has all the great creative functions of nature cooperatively united in himself. For the scientist, even the least of them, is something more than a recording secretary of careful observations, measurements and experiments. He is primarily a knower of worldly ways and a self-adaptive interpreter of what he knows, just as cats and dogs—all of them good scientists in their respective specialties—very well know each other's ways and, rightly interpreting the signs and omens in their world of affairs, adapt themselves beforehand to coming events.

And the human scientist, in so far as he is self-adaptive, is an artist and an artisan, a practical man laboring with hard realities rather than a rhetorician playing with the verbal symbols of his own mental attitudes, or a circuitous thinker vainly chasing the tail of his own thoughts. He seeks rightly to interpret the signs and omens of what is going on within and about himself in order that he may adjust himself to a growing world in a more workable and profitable way.

As an interpreter of his accumulated store of knowledge, he is in his own right a philosopher and theologian of sorts, with all those longings, sensuous convictions and self-satisfying reactions to the apprehension of fundamental truths commonly called religion.

He is also a prophet crying in a wilderness of stubborn realities and uncoordinated experiences, a propagandist, path-finder, reformer and peacemaker. For why should man seek for truth and understanding, if not to sow it and use its fruits to mitigate the inevitable conflicts of life? But the seed can never know its own fruit. So the modern scientist, like primitive man, is still wondering what life is all about and what he *ought* to do about it. Nay, what he *must* do in order to live and grow.

THE EMBRYOLOGICAL BIOCHEMISTRY OF THE DEVELOPING HEN'S EGG[1]

By Dr. HERBERT O. CALVERY

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THE living organism can be distinguished from the lifeless by its inherent property of reproduction. In the higher forms of animal life two cells are usually considered necessary for this process, although possibly the only essential reproductive cell is the egg. The fertilizing cell has, in a few instances, been replaced by simple chemical compounds. The fertile egg may be considered to be a bit of living protoplasm with a highly specialized function, namely, that of reproducing an individual whose organization and characteristics are like those of the species from which the egg arose. We know that the highly organized individual does not exist preformed, minute in size, in the egg, but that an infinite number of physical, chemical and morphological changes must occur before the embryo can emerge fully formed. Of the morphological changes much has been learned in the last century, but of the physical and chemical or physicochemical changes very little has been learned —indeed, Needham closed a review article in 1925 with a remark of William Harvey's: "Neither the School of Physicians, nor Aristotle's discerning brain, have yet disclosed how the hen doth mint and coin the chicken out of the egg."

Some of the obstacles which hinder advancement in the knowledge of embryological biochemistry are rapidly being overcome, chiefly because of the remarkable accuracy of modern microchemical methods, although many difficulties still remain. Most of the investigations that have been made on the chemical changes which occur during embryonic development have been made on the easily available hen's egg, consequently most of the conclusions are drawn from these investigations. There are numerous variable factors which can modify the composition of the egg as well as the rate of development of the blastoderm. The amount of yolk, albumin and water as well as the thickness of the shell may vary with the diet, season of the year and general condition of the animal producing the egg. The velocity of the passage of the egg down the oviduct where the albumin is obtained, the period intervening between the time of laying and the time of collecting the egg, the temperature and humidity of the environment—all are factors which may cause individual variations during development. Fertilization in the upper part of the oviduct initiates development which continues for from eighteen to thirty-six hours, the time required for the complete formation of the egg by the hen. Sometimes the egg may not be laid for forty-eight hours or longer after it has been completely formed, consequently when it is laid development of the blastoderm may have already passed the stage of differentiation into the three germ layers. Such variations in the length of time which the egg remains in the hen make it very improbable that two eggs synchronously laid will contain embryos of exactly the same age. Poultry farmers recognize not only these "body

[1] A large amount of the information in this article has been obtained from the papers of J. Needham published in the *Biochemical Journal*, *Physiological Reviews* and the *British Journal of Experimental Biology*, as well as the papers of H. A. Murray, Jr., published in the *Journal of Experimental Physiology.*

heated" eggs but also the fact that, if a hen sets on the eggs for a time after laying, development will be further advanced than the average.

Another of the difficulties encountered is the fact that the investigator is still very much in the dark regarding the composition of the more important constituents of the egg itself. This is especially true of the proteins, notwithstanding the fact that much work has been done. Very little is known concerning the composition of the albumin, although it is one of the few proteins than can be readily obtained in quantity in a pure crystalline form. Less is known about the yolk proteins, the proteins of the membranes, the proteins of the shell, the pigments and some of the lipids. Until the "static" chemistry of the egg is better understood great precaution is necessary in the interpretation of measurable metabolic changes.

A difficulty more significant than these already mentioned is the indefiniteness of morphological boundaries. Many investigators are not careful to state exactly what procedures were followed. In cases where separations are made into embryo and remaining material, with which should the membrane of the allantois be included? When the shell and its contents are separated, with which should the outer and inner shell membranes be included? When the yolk sac is being withdrawn into the body of the chick, where does yolk end and intestinal contents begin? As Needham has pointed out, the only solution is to adhere strictly to well-thought-out boundaries and to state, when describing the work done, exactly the procedure followed.

The correlation of chemical with morphological changes, in any case, is difficult. The embryologist has been interested only in the early stages of development up to about the ninth day when the embryo becomes adult morphologically, consequently very little is known about the changes in the size and development of the organs in the later stages. However, it is in these stages that the greatest chemical changes occur.

Regardless of these difficulties, remarkable advances have been made in recent years in embryological biochemistry. One of the earliest observations recorded was that the egg normally loses approximately five grams in weight during the developmental period. Nearly a hundred years later it was clearly demonstrated that this loss in weight is almost entirely dependent on the humidity of the surrounding atmosphere. Strange as it may seem, between 1818 and 1840 four different investigators showed that the egg could develop normally in an inert gas such as hydrogen or nitrogen, immersed in oil or coated with paraffin. However, this was soon disproved, and it has been demonstrated in various laboratories that from 3 to 3.5 liters of carbon dioxide are excreted by the egg during development and that a corresponding amount of oxygen is absorbed. Near the end of the incubation period as much as 350 to 400 cubic centimeters of carbon dioxide are exhaled per day, while in the early stages very small quantities are exhaled. It was, likewise, soon demonstrated that all the shell, with the exception of the small part covering the air space, could be varnished and the chick still develop normally. It is through this part of the shell that the embryo breathes.

The question immediately arises, what are the substances used by the embryo in the production of this large amount of carbon dioxide? Is it protein, fat or carbohydrate, or some of all three? Needless to say there are no methods delicate enough to detect the chemical changes that occur during the first few hours after fertilization. Consequently, very little chemical investigation has been made from the time of fertilization to the end of the third or fourth day. Until very recently it was generally be-

lieved that lipids were the entire source of energy for embryonic development. This view arose from the fact that when lipids were determined in the fresh egg and in the fully developed embryo some had been lost, actually about 2.4 grams as an average. This figure corresponded satisfactorily, on calculation, with the loss in carbon dioxide and heat output of the embryo. The correspondence of the figures was not very exact but was thought close enough to show that lipids were the only source. Careful examination of the respiratory quotient after the seventh day gave a value of 0.73, which, unless something very strange was happening, must be considered close enough to the theoretical value for lipids. In the words of Needham, "It might have been doubted, however, that fat was the only important source of energy: there were hints to the contrary in the literature. William Harvey had said, 'and therefore the yolke seems to be a remoter and more deferred entertainment than the white, for all the white is quite clean spent before any notable invasion is made upon the yolke.'" Urea and a considerable amount of uric acid were early obtained from the allantoic and amniotic fluids so that there should have been no doubt of the metabolism of proteins.

Although lipids may have been considered the predominating source of energy, especially in the later stages, it should never have been so considered in the early stages of development, for much evidence points to the use of carbohydrates in this period. The respiratory quotient during the first five days is sometimes as high as 0.95 and thereafter decreases to approximately 0.70, indicating quite clearly that glucose or some other carbohydrate is being burned in the early stages of development followed by the combustion of lipids. This harmonizes with the fact that in the fresh egg there is about 0.5 gram of free glucose present and at the end of five days only about 0.1 gram. Simultaneously with the disappearance of glucose the lactic acid content of the egg rises, reaches a peak and immediately falls to the previously low level. The peak is attained about the fifth day. Also when the glycolytic behavior of embryonic tissue is examined *in vitro* it is found that there is a marked preferential consumption of carbohydrate by the tissue of the three to five day chick.

Still more recently very convincing evidence has been obtained that proteins are also used for energy during the early stages of development. It has long been known that no nitrogen has been lost from the developing egg, consequently the estimation of ammonia, urea and uric acid, end products of protein metabolism, should show definitely whether or not proteins are being burned. Such estimations have been made. The ammonia increases throughout the entire period of development, but in comparison to the dry weight of the embryo it reaches a peak on the fourth day. The amounts of ammonia excreted, however, are very small. A period of intensive output of urea has been shown to occur between the fifth and ninth days. After that time its production does not keep pace with the growth and differentiation of the embryo. The peak of production in comparison to the dry weight of the embryo is on the ninth day, five days after that of the ammonia. The period of intensive uric acid production is from the seventh to the eleventh day, after which the uric acid production does not keep pace with the growth of the embryo. The uric acid peak is seven days later than the point of maximum intensity of production of ammonia and two days later than the same peak for urea. This period of maximum production of nitrogenous waste products, hence the period of maximum intensity of protein combustion, occurs between the eighth day and the tenth day, and this is midway between the periods when carbo-

hydrates and lipids are, respectively, the predominant sources of energy. The protein nitrogen lost by combustion during development amounts to about 7 per cent. of the total protein nitrogen present in the beginning and 3 per cent. of the total foodstuffs burned.

This observation of a succession of energy sources leads to another question. Is it due to the available food supply present in the egg (ovogenic), or is it the order preferred by the embryo itself (embryogenic)? The evidence is in favor of the latter. Large amounts of lipids are always present; all the free carbohydrate is not consumed until the twelfth day and the injection of glucose does not alter the uric acid curve. This is good evidence in favor of the view that the embryo and not its food supply controls the situation.

Energy Sources and the Theory of Recapitulation

The theory that the development of the individual repeats briefly the evolution of the species has been widely accepted by embryologists. It is based on the comparison between the embryonic development of the individual and the comparative anatomy of the species to which it belongs. There is very little biochemical evidence for such a phenomenon; however, it is possible that the order in which the developing embryo selects its foodstuffs may have a recapitulatory significance. The order, carbohydrate, protein, lipid, being the order of selection by the embryo, is also the order of solubility in water, of oxygen content, of ease of digestibility by enzymes of the gastro-intestinal tract and the ease with which they are synthesized by solar energy. Some significance may also be attached to the order in which the nitrogenous end products of protein metabolism are produced. The simplest product of deamination of amino acids is the first to appear, and the most complex is the last. Ammonia, the most soluble and the highest in nitrogen content, is produced first, while uric acid, the most insoluble and the least in nitrogen content, is produced last and accounts for over 90 per cent. of the nitrogen excreted by the chick embryo. Other evidence for the recapitulatory phenomenon is that the invertebrate embryo is relatively richer in sodium chloride than the newly born, the chick is lower by half at fifteen days than at the beginning, the water content gradually decreases, the enzymes of the adult are gradually formed and the membranes of the eggs of some species are not keratin but resemble a mucin. It may be that the ovomucoid of the hen's egg is phylogenetically reminiscent of the time when it was used as a membrane. Further biochemical evidence of this theory will be interesting especially with regard to the succession of energy sources in other embryos and the order of production of nitrogenous waste products.

Some Specialized Phases of Metabolism

A number of chemical changes have been investigated which indicate specialized types of metabolism. Creatin, a substance related to muscular development, is entirely absent from the fresh egg, but its presence has been demonstrated as early as the fifth day and it gradually increases in amount thereafter. Several of the amino acids, substances formed in the breakdown of protein, have been studied. Some of them remain constant throughout the entire period of development, while others show a marked decrease in amount. Inorganic phosphates increase during development, while there is a corresponding decrease in the organic phosphorus. There is a transfer of calcium from the shell to the embryo. The total cholesterol content does not change, although there is a marked change in most of the other fat-like sub-

stances. The purine bases are entirely absent from the fresh egg, but there is a very marked production of them during development. This is without doubt related to the fact that these substances are constituents of the nucleic acid which is always found in cell nuclei. With the rapid increase in the number of cell nuclei of the embryo during the developmental period, it follows, *a priori*, that the purine bases must increase also. Many other chemical changes have been studied, but the findings are so inadequate and contradictory that no definite conclusions can be drawn until these changes have been much further studied. Still other phases of embryonic metabolism have not been investigated at all.

In all the biological sciences the more advanced stage has been the first investigated. Anatomy and morphology preceded embryology; the study of the methods of curing diseases preceded by centuries the practices of preventive medicine; likewise the chemical investigations of physiological phenomena have been confined almost entirely to the changes occurring in the normal adult and attempts are made to interpret all change in terms of the normal adult individual. The fact that a certain change takes place in the embryo does not necessarily mean that the same change will occur in the adult. The fact that a certain phenomenon appears in the chick embryo does not mean that the same thing will occur in the development of the embryos of other species. Neither does the fact that a chemical change occurs in the adult mean that the same reaction will occur a decade in in the future. Life is undoubtedly a procession of physical and chemical changes, some certainly continuing throughout life and into the future generations, while it is just as certain that others continue for a time, then cease, while new ones begin. Consequently any advance in our knowledge of embryological biochemistry is a step in advance toward a better understanding of physiological phenomena in general. The large number of investigations that are being made in this field at the present time give rise to the hope that in the future that remarkable transformation of the inert materials of the egg into the fully developed chick will be better understood and the remark of William Harvey will no longer apply as it still does to-day.

A DISEASE AND EVOLUTION

By Dr. PHILIP R. WHITE

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THERE are certainly more named diseases, of ourselves and of our domestic creatures, plant or animal, to-day, than there were a century ago. Whether there has been a real increase in the number of maladies or only a segregation and renaming of old ones I will leave to the pathologists to decide. But the fact remains. And for any given host there are more diseases. Perhaps plants (for as a botanist I ought to confine myself to them) are evolving susceptibility to sicknesses once strange to them but existent in their neighbors, in the same way that immunities may be evolved. If so, under the old, pre-human order, such degenerates would have been doomed to destruction and owe, then, their preservation to us. Perhaps we are bringing diseases from far countries, unwittingly implanting them on hosts which, being "unaccustomed" to them, have not the resistance to withstand them. Certainly we have enough examples of that to our discredit. And perhaps, too, we are bringing susceptible but previously unexposed plants into regions infected by unrecognized

ILLUSTRATION FROM GONZALES "HISTORIA, ETC."

EDITION OF 1723. IT OBVIOUSLY DOES NOT ILLUSTRATE THE PRINTED MATTER OF THE BOOK. THE TWO TREES AT THE LEFT ARE THE ARTIST'S IDEA OF BANANAS, THOSE AT THE RIGHT PROBABLY PAPAYA. INCIDENTALLY, THE BLACK BOY IS NO MORE AN INDIGENE THAN IS THE BANANA.

maladies, maladies left unrecognized because attacking only weeds of no consequence to us and hence attracting no attention. Whatever the real explanation or explanations, man must acknowledge his major responsibility. He does not ordinarily recognize any obligation to the universe to correct these slips, but sometimes it becomes highly desirable for him to do so. And usually in the end he is successful, I think.

About forty years ago in some of the banana plantations of Panama and Costa Rica there appeared a disease which is now known as the "Panama disease." Bananas had not yet become a household staple, as they are to-day; plantations were small and scattered; the infected areas were isolated. The disease did not then attract much attention. But along with the growth of importance of the host, the disease grew in importance and geographic distribution even more rapidly, so that fifteen years later it had become an important factor in the development of a large industry.

The origin of the disease is buried among the myriad other secrets of the tropic jungles. First noticed, as I have said, in Central America, first described from far-off Hawaii and to-day rampant through most of the New World tropics, the literature can still say of the Old World continents only that it "probably" exists there. It may have come from the Old World to find a too tender host in the probably American-bred varieties of bananas, or with equal possibility it may have lain in ambush for centuries in those wild relatives of the banana, the Heliconias, which are such prominent features of the lowland swamps of the American tropics. Whatever its origin, the disease has definitely fastened itself on a crop which has of late become one of the staples of the American cuisine, and though it has by no means come so near annihilating its host as has the chestnut-blight, it can be compared only to that malady in the violence of its depredations.

If we were dealing with an animal disease and had isolated the offending organism as we have here (for *Fusarium cubense*, the causal agent, was isolated many years ago), even the layman would immediately suggest several potentially valuable methods to be employed. Many such diseases may be controlled with disinfectants of various kinds; others by vaccination and the development of acquired immunity; others yet by antitoxins, the transfer of an immunity from one creature to another. Sometimes there is a carrier whose elimination offers a method of control. Practically all animal diseases, where the life history of the causative agent is known, are amenable to one or more of these methods. But the matter is not so easy with a plant, especially this one. Disinfection of the plant itself is useless, since the disease enters through the soil, which can not be sterilized over large tracts. No antitoxins or vaccines are known for *Fusaria*, and were they known there is no unified circulatory system in the plant to distribute them to the affected parts. There is a carrier, but that carrier is every drop of seepage, the run-off of every rain, the very life-blood of the plant itself. We can not sterilize all the water fed to the plant as we can our drinking water. Altogether the problem of controlling such a disease appears at first quite hopeless.

There is one slim branch reaching above the first wall which bars our path by which, if we are lucky, we may perhaps swing over to firm ground again. When a child is vaccinated for smallpox he usually becomes mildly ill. We say that the vaccination has taken. But among a hundred children there will always be a few who show no initial effect, even under increased doses. The vaccine will not take. They are nat-

urally immune. Now the great mass of work done, especially in the last thirty years, on animal and plant breeding has convinced us that all characteristics of living creatures which are not directly traceable to their surroundings are heritable and may be passed on to their genetic descendants. They, of course, will frequently not be passed on to all descendants, but the important point to us is that they may in any case be transmitted. If a child is immune to smallpox his children will not necessarily be, but they have a better chance of being naturally immune than the children of a child in whom vaccination took. And we are hunting for any chance. But to return to the banana. There are varieties known which are resistant to the Panama disease, but unfortunately they are not very desirable commercially because of other traits. And there are other varieties which are desirable commercially, but again, unfortunately, these are just the ones most susceptible to the disease in question. Knowing the facts of inheritance we might (theoretically) take a poor but resistant variety as one parent, and a good but sickly variety as the other and perhaps (and as long as we can say perhaps, even though it may not carry much conviction, the attempt is worth while) we may get a few descendants out of many which will be both good and resistant. But here again we are confronted by another apparently insurmountable and impenetrable wall for—anomalous as it may seem—no otherwise good banana ever had any progeny to be immune! For the commercial banana is reproduced vegetatively only, by cuttings. It is, as we say, parthenocarpic, producing fruit without viable seed, as most of those of my readers who have eaten bananas will agree. And, what is quite obvious, though you may not have thought of it, if it did produce seeds, it would be no good as a fruit, at least no better than Proserpina's pomegranate (*pomme grainé*, or seedy apple). Now, if by some hook or crook we can inveigle a good banana into having progeny by an immune species or an immune species by a good commercial variety (improbability No. 1), and if further, after we have succeeded in combining our desired characteristics in the way we want them, we can then guarantee that our product will not continue to have progeny (seeds) to spoil the result (improbability No. 2), then and only then will we have reached our goal.

As we have said, the varieties of bananas in which we are interested do not bear seeds. In fact, I imagine few of my readers have ever seen a banana seed. Yet the mere fact of bearing seeds is the only universal characteristic of the higher plants. Is it conceivable that nature has made an exception of this one group of plants? Actually, it is unnecessary to resort to any such far-fetched conclusion. Many, in fact, the majority, of bananas do bear seeds but, quite as we should expect, these varieties are valueless commercially and consequently known only to the initiated. Somewhere, somehow, and as H. G. Wells would say, somewhen, the transformation from seedy to seedless types has occurred, perhaps once, more probably many times. And since nature has made the transformation, perhaps if we can discover the secret of her method we may be able to reverse her process, to produce our first good-immune progeny and then, doubling back on our tracks again, obtain in the end our final seedless-good-immune result. I have set down an appalling number of "perhapses" but science never despairs of doing anything that nature has done before, though the cost may be so prohibitive as to make it inexpedient to do so.

"Somewhere, somehow, somewhen." Where and when are in the past, history, and if it is sufficiently ancient, archeology, and if even more ancient, paleontology (since we are dealing with at least

one-time living creatures). So we shall have to call upon the fellow sciences of geology, archeology, history and ethnology to see if they can not help us burrow under this second wall.

Perhaps a million and a half years ago, in Tertiary times, somewhere nearly coeval with the Peiping man, there lived on the borders of the jungle in what is now Colombia, in South America, a banana, the first to leave us any trace of its existence. It was not such a one as American tourists know in the southlands but more like that seen by Bruce in his search for the sources of the Nile,[1] rearing an enormous, solitary (lacking in "suckers") stem up to form a single thousand-flowered inflorescence with many small fruits the size of one's thumb. Each fruit was quite filled by a small number of black, very hard, smooth seeds, quite inedible. All this we know from the fossil remains, for though only these seeds have been preserved to us, they are sufficiently like the varieties found to-day, in the uplands of Abyssinia, as almost to cast doubt on the authenticity of the fossils![2] In the whole group of bananas to which they belong, only the base of the pseudostem is eaten, and they are only distantly related to our edible forms. Curiously, these seeds are the only fossil remains left to us anywhere in the world, though they, like the fossil camels of our own Southwest, are in a region now long since abandoned by their race. So we have no geological sign of when, where or how sterility originated in the tribe.

> WHEN you make uſe of the Enſete for eating, you cut it immediately above the ſmall detached roots, and perhaps a foot or two higher, as the plant is of age. You ſtrip the green from the upper part till it becomes white; when ſoft, like a turnip well boiled, if eat with milk or butter it is the beſt of all food, wholeſome, nouriſhing, and eaſily digeſted.
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> *From Bruce, "Select Specimens of Natural History."*

DRAWING MADE IN ABYSSINIA ABOUT 1780

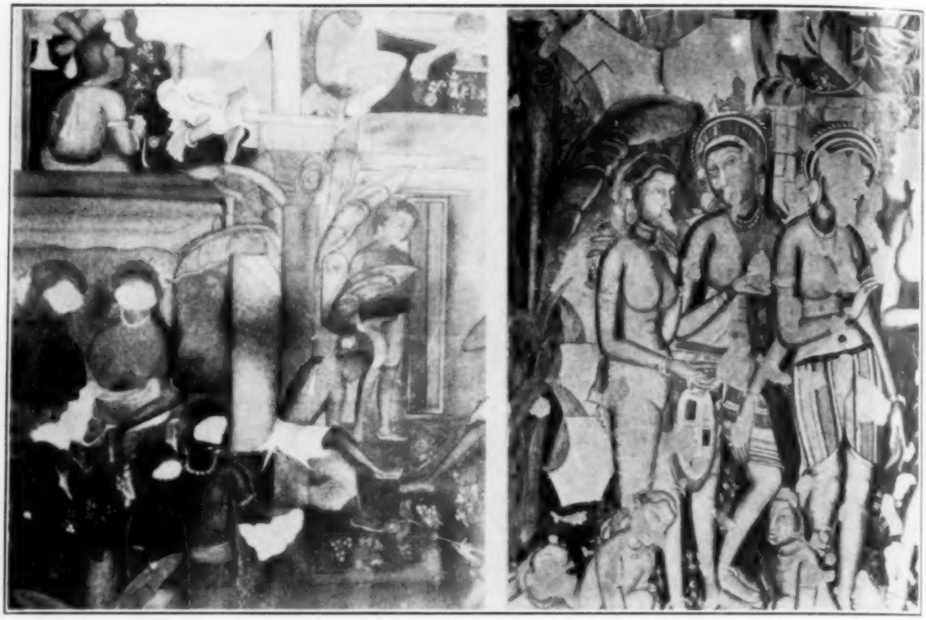
FROM JAMES BRUCE, "SELECT SPECIMENS OF NATURAL HISTORY."

MUSA GLAUCA, THE "VIRGIN BANANA"

PROBABLY THE Τάλα OF MEGASTHENES, PHOTOGRAPHED BY THE AUTHOR ON THE UNITED FRUIT COMPANY'S EXPERIMENTAL PLANTATION AT CHANGUINOLA, ALMIRANTE, PANAMA, AUGUST, 1927.

[1] James Bruce, "Select Specimens of Natural History Collected in Travels to Discover the Source of the Nile in Egypt, Arabia, Abyssinia and Nubia," J. Ruthven, Edinburgh, 1790.

[2] E. W. Berry, "A Species of Musa in the Tertiary of South America," *Proc. Nat. Acad. Sci.*, 11: 298–299, 1925.



—*Portions of plates 6 and 45, Vol. I, John Griffiths, London, 1896–7.*

PAINTINGS OF THE BUDDHIST CAVE TEMPLES
OF AJANTÂ, KHANDESH, INDIA. THE TYPICAL COILED LEAF OF THE BANANA FORMS A CHARACTERISTIC MOTIF IN BOTH PICTURES.

Such chronologies as I am trying to construct are always, at first, fragmentary, but not often so much so as this proves to be. We must leap the whole life span of the human race and half circle the globe for our next point, to the hills of west-central India, in the fourth century before our era. Here, frescoed on the walls of the wonderful cave temples of Ajantâ, in Khandesh, we find pictures of the king's gardens, and in them, quite unmistakable, our bananas; but no fruits are shown, so that these figures are probably of bananas of the Abyssinian type like those of Colombia. What happened in the interim between our Colombian fossils and the Indian monarch's garden? The jungle has buried that secret, perhaps for all time. Nor does subsequent history give us any sign of any more recent example of the sterilization process. A century later (303 B. C.) Megasthenes, then ambassador from Macedonia to Sandrocottus at Palimbothra on the Ganges,[3] described a banana in which, as in the Abyssinian one, the stem (as he says, the inner bark) was eaten, calling it Τάλα.[4] Theophrastus does not name it in any extant fragment but describes the leaf.[5] Pliny,

[3] Strabo, "The Geography of Strabo," translated by Horace L. Jones, the Loeb Classical Library, G. P. Putnam's Sons, New York, 1917: ἐπέμφθησαν μὲν γὰρ εἰς τὰ Παλίμβοθρα, ὁ μὲν Μεγασθενης πρὸς Σανδρόκοττον—2. 1. 9.

[4] Megasthenes: οὕτω μηδὲ Ἰνδαῖσι πόλιας εἶναι μηδὲ ἱερὰ θεῶν δε δομωμένα, ἀλλ' αμπέχεσθαι μὲν δορὰς θηρίων ὅσων χαταΧτὰνοιεν, σιτέεσθαι δέ τῶν δενδρεων τὸν φλοιόν, χαλέεσθαι δὲ τὰ δένδρεα ταῦτα τῇ Ἰνδῶν φωνῇ Τάλα, χαὶ φύεσθαι ἐπ' αὐτῶν χατάπερ τῶν φοινιχων ἐπὶ τῇσι χορυφῇσιν οἷα περ τολύπας.

Karl et Theod. Müller, "Fragmenta historicorum graecorum editore Ambrosio," Parisis, Firmin Didot, 1848–1874.

[5] Theophrasti Eresii, "De Historia Plantarum," Lib. I, Cap. 4, 5–6. Gottlieb Schneider, Lipsiae, 1821.

using Megasthenes' name changed to *Pala*, assumes that Theophrastus' interpretations of his informant's statements were wrong and that where he speaks of leaf, flower and fruit of three trees he actually was describing the three parts of a single plant.[6] If Pliny is right, then Theophrastus does speak of the fruit of the banana, telling how Alexander for-

a R. Mauzi, vel mozi.

De a [*musa*.] *Cap* 491.

Musa quid est? nota est. *Operationes, & proprietates.* b [Nutrit velociter,] & est lenificatiua. & multitudo eius generat oppilationes, & addit in cholera, & phlegmate secūdum complexionem. *Membra anhelitus, & pectoris.* Confert adustioni gutturis, & pectoris. *Membra nutrimenti.* c [Stomacho conueniens est, & multitudo eius] stomacho est grauis valde. Et oportet quidem, vt sumat post ipsam calefactus oxymel cum seminibus, & infrigidatus, mel. *Membra expulsionis.* Augmentum efficit in spermate, & conuenit renibus, & prouocat vrinam.

b R. Nutrimentum eius est paruum.

c R. est grauis stomacho præcipue cū ex ea multū assumitur. Multitudo enim eius.

From Ibn Sīnā, "Avicenna medicorum Arabum principis," edition of 1556. The original Arabic edition was about 1020.

bade his soldiers to eat it as causing dysentery. But I am inclined to believe that Theophrastus was right, in which case the banana he referred to was again of the Abyssinian type. Even those masters of early medieval botany, Avicenna[7] and Ruelio,[8] do not make it clear whether they refer to fruit or stem, and Serapion[9] definitely says that it is the stem and "heart" that was used. It is not until the early part of the sixteenth century with Garcia da Orta[10] and Fernandez[11] that we find the fruit itself referred to definitely as appearing, first in Venice, then in Spain, brought there from Alexandria and thence from India.

MVSA.

Auz.1.Musa Abēmesuai ē calm ī medio primi grad9 humidū ī fine eius nutrit parꝝ & proprietas eius ē cōfere ardori q ē ī pectore & pulmōe & uesica & molit uētré & qui utitur eo multū facit grauedi‹m ī stōaco & opilatiōem ī epate & oportet ꝙ ille qui utitur eo mľtum si cūplio eius ē frigida ut bibat post ipium melicratum aut eximel aut ziziber cōditū Sīdaxar auget fetū ī uētre matricis Alcbale bemē ē medicia bōa pectori & rēibus & ꝑuōcat urīam Liber de medicīa ātiqua excitat libidinē & est graue stomaco.

From Ebn Serabi, "Liber Serapionis agragatus in medicinis simplicibus," Cap. 80, edition of 1473.

[6] C. Pliny, "Plinii Naturalis Historia," XII, 2–6 (6–13). D. Detlefsen recensuit Berolini. Apud Weidmannos, 1886.

[7] Husain ibn 'Abd Allah Ibn Sinā, "Avicenna medicorum Arabum principis, Liber canonis." Basileae per Ioannes Hernagios, 1556.

[8] Joannes Ruellius, "De natura stirpium libri tres." Ex officina S. Colinaei: Parisiio, 1536.

[9] "Abēmesuai ē calm ī medio primi grad' humidū ī fine eius nutrit. . . ." Ebn Serabi, "Liber Serapionis agregatus in medicinis simplicibus translatio Symonis Januensis interprete Abraam judeo Tortuosiensi de arabico in latinum." Mediolanus, A. Zarotum, 1473.

[10] "R– O fructo que em Italia chamam *musa* é por ventura este figo? O– Eu como não fui a Italia não o sei bem sabido, porem soube aqui de alguns Venezianos aqui moradores, que essa fructa ha em Veneza." Garcia da Orta, "Coloquios dos simples e drogas he cousas medicinais da India compostos pello Doutor Garcia de Orta." Johannes de Endem, Goa, 1563.

[11] "E tambien he oydo deçir que los hay en la cibdad de Almería en el reyno de Granada, é dicese que de alli passó esta planta á las Indias, é que á Almería vino del Levante é de Alexandría, é de la India oriental. He oydo á mercadores genoveses é italianos é griegos que han estado en aquilas partes, é me han informado que esta fructa la hay en la India que he dicho é que assi mismo es muy comun en el Egipto, en espeçial en la cibdad de Alexandria donde á esta fructa llaman *musas*." Fernandez (Gonzales F. de Oviedo y Valdes). "Historia general y natural de las Indias, Islas, y Tierra Firma del Mar Oceano." Imprenta de la real Academia de la Historia, Madrid, 1853.

With the voyages of Vasco da Gama and others it was brought to the west coast of Africa, to the Gran Canari, "las Islas Fortunadas" and elsewhere. Simultaneously with the sudden expansion of the horizon of the world we find this most useful of all plants (I say that advisedly[12]) carried from the Canaries to Santo Domingo in 1517.[13] Three years later it completed its voyage to the American continent when it was carried to Peru.[13] Von Humboldt[14] tries to establish its American origin, but the only statement I can find in the authority he cites—Garcillasso de la Vega[15]—can not be interpreted as even implying such a thing as far as I can see.[16] Thus it returns after fifteen hundred millennia to the home of its Tertiary ancestors still keeping the secret which we sought to discover. Geology, archeology and history have helped us not at all.

Linguistics is equally useless, for though we can trace Megasthenes' Πάλα and Pliny's *Pala* to the more modern palam, palon,[17] vala, Kala, Kadla, Kadali, Kadli, Kali (which is evidently the form rendered in the sixteenth century Portuguese of Garcia da Orta[18] as Quelli), Kladi, Klui, Chuoi, etc., and while the Malay pisang of to-day goes back at least to da Orta's Piçam, these tell us only that some banana was a staple at the time these languages arose, at least two millennia B. C. and probably much earlier than that.

My allies have failed to dig under my second wall then. There remains only one recourse. By some scientific third degree we must interrogate the banana itself concerning its past, hidden thus in antiquity. And since it is with the particular variety of commerce, the Gros Michel, that we are especially interested, it is that variety on which we shall center our interrogation. It is here that I can return to my rôle of botanist.

The details of my questioning can be ignored.[19] But the findings themselves are important. We have good reason to believe to-day that every tiny cell of every living creature, whether plant or animal (though we are not quite sure about bacteria and a few others) carries within itself all the potentialities of the creature as a whole, and that these potentialities are the impress of the whole past history of the race (not to imply Lamarckism). Furthermore, these potentialities are born, not in the cell as a whole or even in the entire nucleus, but in those special little packets called chromosomes. If we could read the inscriptions on these cylinders, as we have those

[12] "For that is the fruit they use most at the Indies—they serve them as bread, yea they make wine of them. They eat this fruite rawe like other fruits; they likewise roast it, and make many sorts of potages and conserves and in all things it serveth very well. . . . If this plant were fit for fire it were the most profitable of all others." José de Acosta, "The Natural and Moral History of the Indies," (translated by Edward Grimston, 1609), 1590.

[13] Fernandez, *loc. cit.*, "fué traydo este linage de planta de la isla de Gran Canaria, el año de mill é quinientos y dies y seys años, por el reverendo padre fray Thomas de Berlanga de lo Orden de los Predicadorés, á esta cibdad de Sancto Domingo, é desde aqui se han extendido en las otras poblaçiones desta isla y en todas las otras islas poblades de christianos, é los han llevado a la Tierra-Firme, y en cada parte que los han puesto, se han dado muy bien."

[14] Alexander von Humboldt, "Atlas geographique et physique du royaume de la Nouvelle Espagne," Paris, 1811.

[15] Garcillasso de la Vega, "Primera parte de los Commentarios reales," Oficina real, Madrid, 1609.

[16] Presenteron muchos Conejos caseros, y campestres, muchas Perdices vivas, y muertas, y otras Aves del Agua, innumerables Pajoros menores, mucho *Mais* en grano y mucho amasado en pan, mucha *Fruta* seca, y verde, Mucha *miel* en Panales, y fuera de effos, mucha *Pimienta* de los Indios, que llaman Uchu, cantitad de su Brevaji asi hecho de *Maiz*, como del *Grano*, que llaman Mulli. . . . En suma, no dejaron cosa de las que pudieron traer, que no la trujesen. (Cap. XVII.) Una Embaja, con grandes presentes, que il Inca hiço a los Espanoles.

[17] Fernandez, *loc. cit.*

[18] Garcia da Orta, *loc. cit.*

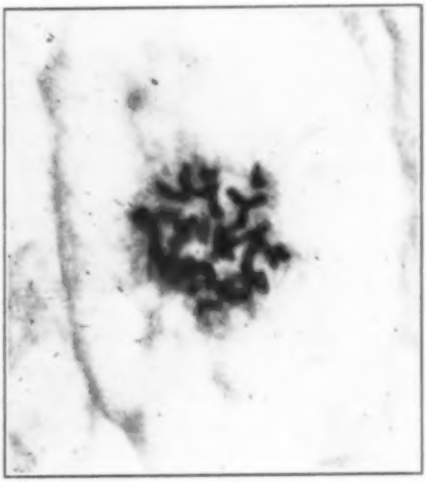
[19] Philip R. White, "Studies on the Banana," *Zeitschr. f. Zellforsch. u. mik. Anat.*, 7: 673–733. 1928.

of Babylon, we could know all the past history of the race, from the creation. I am not so sanguine as to hope for that. The inscriptions themselves must remain sealed to us, for a time at least. But we can read something from the positions in which we find these cylinders lying.

As most of my readers know, when an egg[20] is fertilized by a sperm,[20] the egg carries with it a certain number of these packets bearing half the characteristics (half the past history) of the mother,[20] and ordinarily the sperm carries an equal number of packets bearing half the characteristics of the father[20] so that the progeny will have the sum of these packets. If mother and father were closely alike this sum will then very closely approximate both parents. And when the parents were alike and their parents, to several generations, that is, when as we say they were homozygous, these little packets from mother and father are so much alike that they fall naturally into pairs and remain so until such a time as new eggs and sperm are to be formed. Throughout most of the life of the organism this pairing is rather loose, and if one sees two such packets quite separated, one is not disturbed. But just before new germ-cells are to be formed, the elements from father and mother seem to draw together into closer union before separating definitely to the daughter cells. This stage is what we call the synphase (syndesis), and if at this stage we find our little packets lying not in pairs but scattered, and if, as usually then happens, these packets are not distributed in even numbers to both daughters, we can be sure that something is wrong.

This is exactly what happened when I came to interrogate the banana under the microscope. If I took a piece from a root, or (though the roots are the

[20] Because the phenomena here outlined are characteristic of both plants and animals I have borrowed the terms sometimes restricted to the animal field.



PHOTOMICROGRAPH OF THE CHROMOSOMES

FROM A ROOT TIP OF THE "CHEVALIER" BANANA, ONE CLOSELY RESEMBLING THE GROS MICHEL BUT HAVING THIRTY-SIX INSTEAD OF THIRTY-TWO CHROMOSOMES. THE MAGNIFICATION IS ABOUT 2,500 TIMES. PREPARATION BY THE AUTHOR.

easiest to work with) from the stem or leaf or flower body, and examined the nuclei I found thirty-two neat little black packets, some straight, some crooked, but always the same number. Now if the parentage of our banana had been quite proper and above board I should have found at syndesis sixteen neat pairs. But I did not find sixteen pairs. Instead there were only twelve pairs. The other eight packets were scattered, unattached, and when the daughter cells were formed, these eight were often not evenly distributed. At last I had found a question in the answering of which my banana had exposed itself and given me a glimpse into its past.

There are several ways in which such a grouping of our little packets might have come about, but only one is backed up by more than the slimmest possibility, and it is that one that we shall consider. If a sperm containing twelve

chromosomes were to fertilize an egg containing twenty chromosomes only twelve of the egg's chromosomes would find mates and there would be left over eight "old maids." So long as the social intercourse among chromosomes was general and the vegetative prosperity permitted a single unified community, they would behave quite normally, but when hard times forces the community to divide and those who can, choose mates (excuse my metaphors!) these eight would be left to wander aimlessly on the boundary between the two communities to fall at hazard into either one or the other.

I believe that some such thing happened here.

The banana has then told me a little concerning itself. It has told me that one of its parents gave it twelve chromosomes and the other twenty, though it has not told me which parent was which. But that does not matter so much in bisexual plants as it would in unisexual animals. Since each parent gives its offspring only half of its characteristics one parent must have had not twelve but twenty-four chromosomes while the other had not twenty but forty.

The conclusion is perhaps not obvious. We started with the supposition that it was necessary to use the Gros Michel as a parent, and its parthenocarpic sterility presented a seemingly insurmountable barrier. But now another possibility presents itself. The Gros Michel has hinted to us that perhaps, just perhaps, we can discover who its parents were. And if we can, and one of them is immune to Panama disease, why not breed them again, and produce a new immune Gros Michel? It is not, of course, certain that either or both parent varieties is now living, for much can happen in five or ten or twenty thousand years, but at least we can look.

It may surprise my readers to know that there are not less than, and probably more than four hundred named varieties of bananas from which to choose. That means something like 160,000 possible combinations—quite a formidable array. But let us not be discouraged. Let us delve a bit deeper to see if it will be possible to eliminate some of these four hundred. I have not been able to interrogate all of them, for many are still hidden in the jungles of India, Malaya, Burma, Siam, Cochin China, the East Indies and elsewhere. But, thanks to the United Fruit Company's extensive collection in Panama, I have studied some 150 of them, with again moderately encouraging results.

Out of them all one single variety, a native (?) of the Philippines, answered to the call of twelve chromosomes. This is not one of those we wanted unless under the influence of cold or some other untoward agency it might be induced to give not half but all its chromosomes to its progeny (this has been done in some apples and fireweeds). So we will not discharge the witness yet but relegate him temporarily to the bench. Nor did I find any with sixteen chromosomes, although Tischler found one such in East Africa (a descendant of one of Vasco da Gama's importations?). Of those with twenty chromosomes all but two are obviously "not guilty" for three of them are of the type of the Abyssinian banana, six are "hemp bananas," very different from any other group, and only two, one from New Guinea and one from the Philippines, are possible culprits, even under the unusual conditions suggested for the twelve types. But thirty-seven varieties answer to the number twenty-four, one of our potential culprits, twenty-one of them from the region of the Far East where bananas presumably took their origin: Java, Sumatra, Burma, Malacca, Siam, Farther India, etc. Many of them are much alike, but there are at least eight distinct species among them. These must be set aside as among the possible culprits. There were in our collection three more

with this number which we had ourselves created (hybrids), two with twenty-three chromosomes and three with twenty-two. Only a single wild variety, from Cuba, had twenty-eight chromosomes, but interestingly, one of our synthetic varieties, the progeny of a twenty-four and a thirty-two, had the same number, showing the possibility of such intermediate numbers arising by artificial methods.

And now we come to our thirty-two-chromosomed types, the first cousins, perhaps, of our Gros Michel. No less than fifty-nine varieties with this number appeared. Most of them, like the Gros Michel, are sterile and they represent most of the edible forms. Only a single one, "Ta Ni Pa" from Siam, often produces seed, and six others occasionally do. It seems probable that we can discharge all these as definitely not implicated. In the same way, although thirty-six varieties showed thirty-six chromosomes each, only two of them occasionally producing seed, many of them are quite indistinguishable from the Gros Michel. The implication is that one of their parents was the same as Big Michael's. At any rate, we can not accuse them of parenting him. I found no varieties with forty-four or forty-eight chromosomes and find the latter mentioned only by Tischler, who was unable to tell me anything more about his variety other than that it came from Java and bore a name which suggested that it might have come originally from India (Pisang Kladi).

"But you have not mentioned any which answer to the name of forty—one of those which you need as possible parents for your Gros Michel!" True, I have left those for the last. For I found them only at the last moments of my search. I had almost given up, almost ready to acknowledge that I might have been mistaken in his parentage, that perhaps the probable origin of that peculiar combination 12–20 was not the true one. And then, in the last dozen out of all those hundred and fifty witnesses to be interrogated, I found two (no, only one!) possible culprits. Two varieties showed forty chromosomes, so that my prediction made nearly a year before that such a one would be found was fulfilled. One of these was a variety from the Philippines, going under the alias of "Tiparot," and might be one of our culprits. But the other one was not a wild species but a synthetic one, a hybrid! And further wonders, we knew who its parents were! Its mother was an occasional seeding variety with thirty-two chromosomes. On the basis of our theories its father should have had forty-eight chromosomes. Yet we knew, or thought we knew, that there were no forty-eight-chromosomed types in all Panama! Could we have been mistaken? No. That other parent was a twenty-four-chromosomed banana of the "Basjoo" type. Through some anomaly such as we had envisioned as a possibility but not a probability for our twenty-chromosomed types, the father had given not half but all his chromosomes to his progeny! And this progeny was actually more viable, more fertile than either of its parents! It could not possibly have been a parent of the Gros Michel, since it was created at least a hundred and probably many thousands of years after the creation of the Gros Michel, yet it was excellent as a potential parent of such types! What could be a better demonstration of the potential feasibility of our original plan?

How many possible parents have we now to consider? Discarding all (1) sixteens, all (1) eighteens (I had put that among the twenties for reasons irrelevant here), all twenties of the Abyssinian and "hemp" types, all (6) twenty-twos and twenty-threes, all (59) thirty-twos, all (36) thirty-sixes, my one synthetic forty, all (1) forty-eights and all hybrids, we have left 38 twenty-fours, 2 twenties, 1 twelve and a single forty, a

total of not more than 138 possible combinations, instead of the 160,000 that we started with. True, there are some 250 more varieties that we have been unable to take into our survey, but even so it is doubtful if we should find enough new twenty-fours and forties to bring the combinations to a very unwieldy total.

Thus, where geology, archeology, history and ethnology have failed to burrow under our second wall, by planting our banana itself thereon we have sundered it. Now the problem must pass from my hands, as a cytologist, to others; to the plant explorer to search out in the jungles all other types of bananas to be included in our survey; and to the plant breeder, to take these possible parents and test out their progeny, to see now whether it will be experimentally possible really to combine fruit characters, productivity, immunity to disease and seedlessness, in a single super-banana. And our third wall now appears far less formidable than it did at first, for we see that in trying from seed-producing varieties to produce seedless ones we are only attempting what one group of animal breeders does constantly, namely, the mule breeder. Taking choice mares and asses, fertile, he produces a hybrid progeny which is always sterile. So long as we thought of the Gros Michel itself as the important race, the double reversal of sterility-fertility-sterility seemed our only recourse, and a very difficult one. But, looking at our Gros Michel now as a hybrid and its parents as the important things, we can face the dilemma with equanimity since it melts into thin air. We do not have to reverse our initial sterility since it does not exist in the parent and we have good reason to expect a sterile progeny. Perhaps we shall conquer our disease yet. Surely it is worth trying!

At the risk of appearing anticlimactic I am going to present another aspect arising from this study, that of genealogy and of evolution in general. You will notice that in the figures I have given, out of 150 varieties only eight have numbers which are not multiples of four. These were eighteen (1), twenty-two (4), twenty-three (2) and thirty-four (1), and of these 1 twenty-two and 1 twenty-three were known to be hybrids. This gives us some insight into how the whole race of bananas may have evolved.

It is a well-established rule that the basic number for such a polyploid series, as we call it, must be not more than twice the highest common divisor of the species numbers (known or unknown, of course, since it must include extinct species as well as existent ones). Now throwing aside these eight as being obviously aberrant, we may take eight as our basic number. I might expect to have found such a one, but since the race with which we are dealing began with that number at least a million and a half years ago and probably much more, it does not disturb me much to have failed in my search so far. Perhaps it still does exist in the jungles of Malaya. As we have demonstrated experimentally in synthesizing our forty type, it is possible for a sperm or egg, under some conditions, to carry with it not the usual half number of chromosomes but the whole number. Now that half number (starting with eight as our first whole number) is four and the whole number is eight. Their sum is twelve. This number we find in one of my specimens from the Philippines. If both egg and sperm bore not the half but the whole number the sum would be sixteen, as we actually find it in Tischler's East African variety, "Dole." I could, of course, now cross my twelve and sixteen to get eighteen, but I prefer not to for many reasons, chief of which is that I have found only one eighteen and that obviously derived in another way. But let us continue our doubling process for a little while. In the case of "Dole" we are perhaps justi-

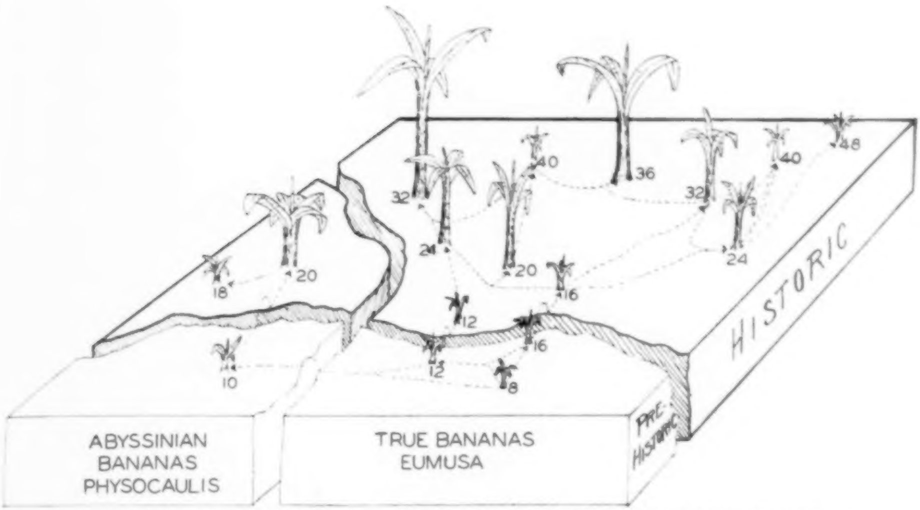


DIAGRAM ILLUSTRATING THE POSSIBLE INTERRELATIONSHIPS OF THE VARIOUS GROUPS OF BANANAS. THE SIZE OF THE PLANT IN EACH CASE REPRESENTS THE RELATIVE FREQUENCY OF OCCURRENCE OF THE CHROMOSOMES GROUP TO WHICH IT BELONGS.

fied in doing this (or rather assuming that it has been done) by our supposition that it had just completed one doubling under extraordinary conditions. In the case of our "Philippine unidentified" (as it is designated in my records) we are even more justified by the well-known fact that a heterozygous hybrid often makes itself homozygous by the simple expedient of splitting all its chromosomes in two (or perhaps separating them and bringing them together again by uncompleted cell division) thus creating its own pairs. We should then get a fertile thirty-two (which we have in our single representative "Ta Ni Pa") and a fertile twenty-four which is represented by our large "Basjoo" group (one of our probable parents for Gros Michel, you will remember). Now cross "Basjoo" (twenty-four) and "Dole" (sixteen) and we have twenty, representing our hemp (textilis) group which doubles to form one forty type, "Tiparot." Cross "Basjoo" (twenty-four) and "Ta Ni Pa" (thirty-two) and we have twenty-eight, our single "Dorado," a poor, sterile, useless hybrid (the odd-numbered multiples are usually poor) which could not even double itself further and would probably have been doomed to extinction in the mills of natural selection, had it not been for us prying botanists. Cross "Ta Ni Pa" (thirty-two) with "Dole" (sixteen) and we have another twenty-four type, possibly "Lady Finger," which being an even-multipled hybrid doubles to form a forty-eight "Kladi." We have already crossed one thirty-two type (in that case "Apple Plantin") with a twenty-four type, "Bastard Hemp" (probably a "Basjoo") to get our anomalous synthetic forty, instead of the expected twenty-eight. And we have supposed this forty to have crossed with a twenty-four to produce "Gros Michel" (thirty-two) and with a thirty-two to have produced "Pisang Sri" (thirty-six). And here again we have incidental evidence of the validity of our suppositions, for we see now why, perhaps, "Pisang Sri" and "Gros Michel" are so much alike, for both have exactly the same grandparents and one parent of the two is the same. No wonder they

are alike! We might theoretically carry on this doubling and hybridizing to infinity, but as I have said, odd-numbered multiples and, even more, fractional multiples (22, 23, 34), have a very low survival value. Moreover, as we mount our tree the numbers increase, the balance of characters becomes more delicate and hence the high numbers are less likely to survive. And perhaps, also, two million years is not long enough for higher numbers to have had time to evolve!

But what of our Abyssinian banana? Probably somewhere back in pre-Tertiary times a twelve type crossed with our ancestral eight, giving ten, and this then doubled to form the twenty of the Abyssinian. This is quite a different origin from the "textilis" twenties and much more ancient. And this in turn lost two of its chromosomes to form our single eighteen. Perhaps Professor Muller's cosmic or earth rays caused these chromosomes to fuse sometime in their bearer's travels between Colombia and Abyssinia (we can not say in which place, if either, they originated). At any rate we now have a pretty complete though admittedly hypothetical genealogical tree.

We have shown, then, a method by which the problem of disease control may be attacked by one who is not a pathologist. And we have broached another even more fundamental problem. In a recent issue of this journal there appeared a paper by Professor H. J. Muller entitled "The Method of Evolution."[21] I should prefer that he had entitled it "A Method of Evolution," for though the evidence of the existence of mutations is unquestionable and the evidence for the activity of cosmic and earth rays in producing these mutations grows from day to day so that I should certainly not concur with Professor Jeffrey in ridiculing this method, I nevertheless feel that the evidence for concomitant evolution by hybridization is even better established, and that, while perhaps it is not so fundamental in scope as is the "ray" evolution, it has played a much more obvious and far-reaching rôle than has the former. This polyploid genealogy is not an isolated example but is typical of whole family groups and also occurs (perhaps of a different origin?) in Professor Muller's own fruit-flies. But I do not wish to be drawn into any controversy over the methods of evolution, so I will leave it to my readers to judge of the validity of my conclusions.

[21] H. J. Muller, "The Method of Evolution," SCIENTIFIC MONTHLY, 29: 481–505, December, 1929.

THE TREE THAT DOES NOT YIELD A PROFIT

By W. W. ASHE

U. S. FOREST SERVICE

Upon the tomb which marks the grave of a Bishop of Chichester there is said to be this inscription, "I shall come this way but once," and this seems to be the point of view of many who have cut trees into lumber, that they shall never return for a second cutting, or to see the outcome of their labors. As a result of this outlook there are in the United States, according to estimates of the U. S. Forest Service, about eighty-five million acres of land that might be producing timber but instead are standing idle. This area of idle land is about twice the size of the State of Virginia.

This problem of our devastated and idle cut-over woodland has been intimately associated with another problem, "The tree that does not yield a profit." It has been the general policy of sawmill men to cut every tree above sapling size, to cut clean, as they say. This method was often followed because they were unable to decide as to what size it was not profitable to cut, often because, having purchased and paid for the timber, they were apprehensive lest profitable material would be left for which they had paid. There has been justification, however, for this dilemma.

Few problems in industrial engineering have been more perplexing than the determination of the size of the tree which it pays to cut and the relative profits which can be made from cutting and manufacturing into lumber trees of different sizes. As a result of this ignorance millions of small trees have been yearly sacrificed, contributing only a loss to those that cut them.

This problem of the unprofitable tree has been perplexing to those engaged in selling trees and one equally as perplexing to those manufacturing trees into lumber. It has been a serious problem to the large as well as the small sawmill operator. Does it pay best to take out all trees for sawlogs or if it pays to leave trees, trees of what size, and how many? The sawmill owner's interest in and his consideration of this problem is primarily not from the point of view of what is best for the land, but rather entirely from the point of view of the profits and relative profits in turning sound trees into salable lumber—of liquidating his investment in timber.

Methods have been worked out for solving this problem—solving it satisfactorily even to skeptical mill managers and superintendents and to quizzical boards of directors—and by solving it thus taking certain elements of cost keeping in the lumber industry out of the category of empiricism. This crepuscular zone of trees of doubtful profit can now be fully illuminated.

Investigations conducted at different classes of mills, large mills as well as small mills, and made in different states in widely separated regions have clearly demonstrated that a large portion of the small trees above sapling size which are at present being turned into lumber are being converted at a loss or at best merely at a nominal profit. That is, there are marginal and submarginal trees just as there are marginal and submarginal agricultural lands—lands which can not be cultivated at a profit—trees which can not be cut at a profit, though standing cheek by jowl with larger trees that are profitable.

Each sawmill operation has its own

—*Photo by W. W. Ashe*

A STAND OF RED PINE IN MICHIGAN

WHICH PROBABLY WILL BE CUT CLEAN AND ITS INVESTMENT VALUE DESTROYED OR MATERIALLY IMPAIRED. NO INFORMATION IS AVAILABLE AS TO THE SIZES TO WHICH TO CUT WHITE OR RED PINES TO SECURE MAXIMUM PROFITS.

diameter of maximum profits, and the figures which are secured at one operation consequently may not be applicable to another. While this is the case, there is within a given region and for a designated kind of timber a comparatively narrow range of variation. The results of these investigations may thus be standardized by regions and by kinds of trees.

The difference in the cost of operating large and small trees results from several factors. One is that far more weight of wood must be handled in producing a foot of lumber from logs which are cut from small trees than in producing a foot of lumber from logs from large trees. So long as the wood is in the log, the weight of the bark must be considered and added, since the bark is a part of the log through all its handlings until its journey as a log ends upon the saw carriage, where the log is sawed into boards. Since more weight must be handled, more labor and a longer time are required. The difference in the weight of wood which must be handled is roughly indicated by the number of square feet of board which can be sawed from a cubic foot of solid wood. Only 2.5 square feet of such lumber can be manufactured from a cubic foot of wood in trees eight inches in diameter, but 5.4 feet of boards can be produced from logs taken from trees which are sixteen inches in diameter. Logs from trees twenty-four inches in diameter, however, yield 6.8 board feet to each cubic foot of solid wood. That is, there is a far larger proportion of wood lost in the form of sawdust, slabs, edgings and trimmings in sawing up the smaller trees.

Neglecting the difference which results from the variation in the proportion of bark it may be said three times the weight of logs must be handled in moving eight-inch trees that is handled in moving twenty-four-inch trees through the different logging processes necessary to produce a thousand feet of boards. This carries the log up to the time when the boards drop from the teeth of the saw. Not only must more cubic feet of wood be handled but also more trees and more logs. Seventy-eight logs cut from eight-inch trees are needed to produce a thousand feet of boards, but only one and one quarter logs are needed from a tree twenty-four inches in diameter to produce an equal quantity. But the difference in time and labor is not confined to the handling of logs and to the different steps which involve merely the handling of logs. Even after the logs are sawed into lumber the evil dryad which resides in the smaller trees still follows the lumber made from them. If the trees of different size are considered on the basis of the number of pieces of board which are sawed from them in place of the weight or number of logs there is still a most unfavorable showing for the small trees. When these smaller 78 logs are manufactured into lumber they produce 240 separate and distinct pieces of board. The twenty-four-inch trees, however, saw out only 114 pieces of board to the thousand feet. That is, more than twice as many pieces of board are manufactured from the small trees as from the large trees, but unfortunately these boards from the small trees are of narrow width and often of shorter length. It requires, however, as the investigations have shown, essentially as much time for a laborer or a machine to handle a narrow board as a wide one.

Suppose these differences in the number of trees to be felled for making a thousand feet of lumber, in the number of logs which must be sawed up, in the number of pieces of lumber which must be handled, are translated into relative time or costs of handling. Costs, however, will not vary exactly in the same proportion as the number of pieces of

—*Photo by W. W. Ashe*

A STAND OF HARDWOODS

IN THE MOUNTAINS OF NEW ENGLAND, WHICH ON ACCOUNT OF THE LARGE PROPORTION OF SLENDER TREES OFFERS AN EXCELLENT OPPORTUNITY FOR THE APPLICATION OF THE PRINCIPLE OF CUTTING FOR MAXIMUM PROFITS.

lumber, as the number of logs or as the weight of logs. Exact costs for handling trees of different sizes have been secured by timing each step in the logging woods and in the sawmill operation. This timing began at the stage when the tree was notched, that is, when the little chip was taken out of its base which determines the direction in which the tree will fall. The stop watch followed the felling of the tree and kept the time through the different steps to the final act of all, when the lumberman bade good-by to his product and the finished lumber ready for use was loaded in cars for shipment to the distributing yards in towns and cities.

Such investigations have been conducted at a number of plants, among others at that of the Crossett Lumber Company, which manufactures at its Arkansas yellow-pine mills more than forty million board feet of lumber a year. The figures secured at this and at other plants as a result of these investigations have been averaged. They show that during the time required to fell and to cut into logs enough eight-inch trees to produce 1,000 feet of boards enough logs can be cut from twenty-four-inch trees to produce 2,500 feet. For this activity it is two and a half times as costly to handle eight-inch trees as twenty-four-inch trees. The actual cost of this and other activities will vary in different parts of the country as wages vary, but the relative costs for trees of different sizes at any specified operation will vary essentially as does the relative time which has been determined for this activity.

Another important step is sawing the logs into boards. It costs at a supposedly efficient band sawmill operation in Alabama more than $9 a thousand feet to convert into lumber the logs which are cut from trees eight inches in diameter. At the same mill it costs less than $2 to saw an equal amount of lumber from logs taken from trees twenty-four inches in diameter. For sawing one thousand feet of boards at this sawmill the ratio of cost is four and a half times as much in the case of the smaller trees as for those of larger size. Nevertheless, this ratio is not exceptionally high for mills of this class which are primarily for handling logs of large size rather than very small ones. Notwithstanding the relatively higher cost of handling such small timber, many trees of this size were daily felled, hauled to the mill and sawed up. The low cost and the profits made in handling the large timber absorbed the high cost and the resultant loss in converting the small timber, and no one was the wiser. It is a proverbial case where ignorance is bliss.

In a circular sawmill the respective costs for sawing one thousand feet of boards were $4.50 and $1.20. The ratio of cost is still nearly four to one. It must be understood that the ordinary portable circular sawmill is designed primarily for handling logs of medium size, and while this mill showed somewhat greater efficiency in sawing up very small logs than in sawing up those from trees as large as twenty-four inches in diameter, there was a rapid decline in its efficiency in handling logs of a very large size.

Felling and sawing into boards are by no means the only steps in a sawmill operation, but to the casual observer they stand out as the important processes. In an ordinary lumbering and sawmill operation involving a large-sized unit, making use of the type of mill known as a band saw and necessitating a logging railroad to bring the timber from the woods to the mill, there are twenty distinct activities or divisions of cost. The costs of some of these activities are not affected by the size of the tree. Some are influenced by the total amount of timber which is cut.

The total cost of the sawmill or railroad is the same regardless of the size of the trees or the amount of timber. The larger the aggregate amount of timber which can be cut or which is available for transportation the smaller is the amount which must be charged against each thousand feet of timber for erecting the mill and for building the railroad. These items are known as construction costs or construction overhead costs. Likewise, there are some items of cost like drying which are essentially constant, regardless of the amount of timber which is cut or the size of the trees from which the lumber is manufactured. The average sawmill operator as a rule claims that after a mill has been placed, after the railroad has been constructed or a road graded or improved, it is more economical to cut the smaller trees than to leave them. In case the timber has been purchased at a lump sum this is a further incentive to cut clean. Frequently this "pound of flesh" is taken at a dear cost.

After making a full allowance for the increase in the cost of manufacture, because of distributing the construction costs over a reduced cut of lumber, it has been clearly shown at the operations investigated that even the trees of what might be called medium size are being cut at a loss. Other trees are cut which yield only the scantiest profit, too little in fact to make a satisfactory return on the investment. This is particularly so in the eastern states in the operation of the class of timber known as second growth in which close cutting is the prevailing practice.

The plants at which these investigations have been conducted are typical plants, cutting typical stands of timber. The conditions at these mills can be duplicated at many others. The stands of timber were quite similar to many stands which farmers sell to sawmill men or which they themselves cut.

So far only operating costs have been considered. These investigations likewise show that a thousand feet of boards sawed from large trees have a far higher selling price than the same amount of lumber sawed out of smaller trees. The comparative values of the lumber of southern shortleaf pine are available. The graded lumber sawed from such trees eight inches in diameter has a mill value of less than $13 per 1,000 board feet. The lumber from such trees sixteen inches in diameter has a value of about $20.50 per 1,000 board feet. That from twenty-four-inch trees has a still higher value, $23.50 per 1,000 feet, or nearly twice that of the lumber from the eight-inch trees. At the same time it costs nearly three times as much to manufacture the lumber from these small trees. It is this combination of increasing costs and decreasing value as the size of the tree becomes smaller that secures the attention of the operator.

When the selling price of lumber and the cost of manufacture were compared it was found in an investigation made in a large operation in southern Arkansas, with large investment in sawmill plant and railroad, that the highest profits were being made by cutting no tree below sixteen inches in diameter. To cut to this diameter reduced, of course, the total amount of lumber made. This reduced cut, however, was more than offset by the increase in the price of lumber as a result of eliminating the large proportion of low grades in the smaller trees and the higher cost of handling them. In a portable sawmill operation investigated in Alabama the greatest profits per 1,000 board feet were realized by cutting no trees below eighteen inches in diameter.

This problem so far has been considered entirely from the point of view of the sawmill man. Even when he cuts to secure the maximum profits, in most cases a large number of medium-sized

trees will inevitably be left. Some large concerns like the Crossett Lumber Company, for whom investigations of this kind have been conducted, are cutting very conservatively. This company's acute cut-over land problem is a problem of unproductive lands that were closely cut over before it adopted its present cutting policy. These lands amount to many thousands of acres out of a total of about 500,000 acres owned in Louisiana and Arkansas. The difficulty with which the company is confronted in rehabilitating these devastated lands has been overcome to a great extent in the case of lands which it has cut over more recently through the adoption of these scientific cutting methods. These methods were based upon a thorough analysis of the costs of the operation. This analysis showed that by observing a higher diameter limit in cutting the mill would secure a higher aggregate profit from its entire operation than if it continued to cut to a smaller size or even to cut clean.

The Crossett Company, and such other concerns as have adopted a similar cutting policy, are securing the highest profits from their operation. They are cutting no trees which a complete analysis of their operation has shown to be unprofitable. This policy has been extended by some companies so as to leave many trees which could be operated at only a nominal profit. The result is that such concerns can look forward to a profitable recutting of lands at an early date. This second cutting in some cases will have the benefit of trees nearly as large as those in the natural virgin stand and will yield a large proportion of the high and valuable grades of lumber. It will have low logging costs and often will result in conditions which will permit the operation to be continued indefinitely.

A further and likewise an important aspect of this problem is the influence which the failure to cut these small trees if adopted as a general practice would have upon the lumber industry itself. Few private investors will consider waiting sixty or even forty years for growing a crop of saw timber from the seed without assurance of profitable intermediate returns. Leaving these trees of the size of telephone poles or somewhat larger will go far towards perpetuating the lumber industry on its present industrial foundation, through furnishing in the early future the timber of sufficient size to produce the customary proportion of grades of lumber for which the American market calls.

Likewise, through the general use by land owners of the conclusions from these investigations it may be possible to avert for at least a portion of the remaining uncut forest lands the overwhelming disaster which has overtaken the more than eighty-five million acres already unproductive chiefly as a result of too close cutting in the past. As a rule, such of our pine lands as are in private ownership are still being cut clean or nearly so. It is true that a few small trees of around sapling size are being left, but only a few owners as yet require that larger trees of the size of telephone poles and larger shall remain uncut. Trees of this class would within a year or two furnish seed for restocking and, more important, by their added growth they might in a few years more supply material for a recutting. The fact that these pole-sized trees can be converted into lumber at only a nominal profit at best at once presents the most important reason for not cutting them. If they are left, and the owner of the land realizes the possibility of an early second cut, there is an incentive for him to protect his land, to care for it as an investment. This is one, and perhaps it is the most important, of the public relations aspects of the problem of the small trees. Had this system of cutting been

—*Photo by W. W. Ashe*

GROUP OF SHORTLEAF PINE-TREES

IN ARKANSAS THREE YEARS AFTER CONSERVATIVE LUMBERING UNDER MAXIMUM PROFITS PRINCIPLES. THESE TREES COULD HAVE BEEN REMOVED ONLY AT A LOSS, YET A FEW YEARS BEFORE ALL SUCH TREES WERE BEING CUT IN THIS OPERATION. AS THE RESULT OF ENORMOUSLY ACCELERATED GROWTH FOLLOWING ISOLATION THESE TREES IN LESS THAN TWENTY YEARS WILL FURNISH A PROFITABLE SECOND CUT. AS MANY AS TWENTY SUCH TREES ARE BEING LEFT PER ACRE.

applied in former years the area of waste land would not be nearly so large.

These waste lands are yielding their owners no income, and there is no possibility of income from them for many years to come. They are lands in which the owners have largely lost interest as active investments; lands which the owners hope to sell, to pass on to some one, perhaps to subdivide and retail for farming purposes; lands that lack any element of present value characterizing a fair investment or any hope of early and constant returns even at a low rate of interest. State and county, moreover, lose revenue from such lands, for on the whole in the long run they yield but little in the way of taxes. Fortunately, the eighty-five million acres are scattered among many states. The burden of carrying them, for it does impose the burden of extra taxes upon other property, is therefore somewhat distributed, though it falls as a rule upon the poorer and less able communities. Owners of large areas of such lands, particularly in Michigan, Wisconsin and Minnesota, have in fact given them up rather than continue to pay taxes. In Michigan alone more than 700,000 acres have reverted to the state.

The unfortunate situation is that the area of such land is increasing, increasing at the rate of more than a million acres a year as timber lands continue to be cut without due regard for their future earning powers, without an attempt being made to preserve their investmental value.

In the past sawmill communities have been ephemeral. On account of this the employees have been at a disadvantage as compared with those in other industries where continuity of employment was assured. Since the life of the mill operation was limited, buildings were often of poor construction and living conditions below the general prevailing standard. School facilities are still often inadequate. It was necessary in the limited operation that the entire investment in buildings and in mill plant be paid for out of the original stand of timber. If most sawmill operations, as seems possible as a result of these investigations, can be placed upon a continuous basis, the sawmill becomes a permanent wood-using industry. It becomes a fixed asset of the community. It should never be cut out. The complete payment for the plant and buildings need not be charged off against the cut of timber during a limited time, but merely repairs and upkeep and a nominal yearly amortization charge. It means, moreover, sustained public revenue for the counties in the way of taxes.

This is the most desirable situation which could possibly develop in the American sawmilling industry. The result of the general adoption of such plans eliminates the possibility of any great additional increase in the area of waste forest land, particularly in the eastern, southern and lake states. It places the concerns that make use of this principle in a most enviable position as forest land owners. The large old growth timber of the East is nearly cut out; the mills that carry forward these slender trees to become large-sized timber can look forward to producing quality lumber at low cost. Such mills as will be exclusively dependent upon young second growth stands containing only trees of small size must be content with knotty logs and with high cost of production.

HYDRAULIC LABORATORY RESEARCH AT THE STATE UNIVERSITY OF IOWA

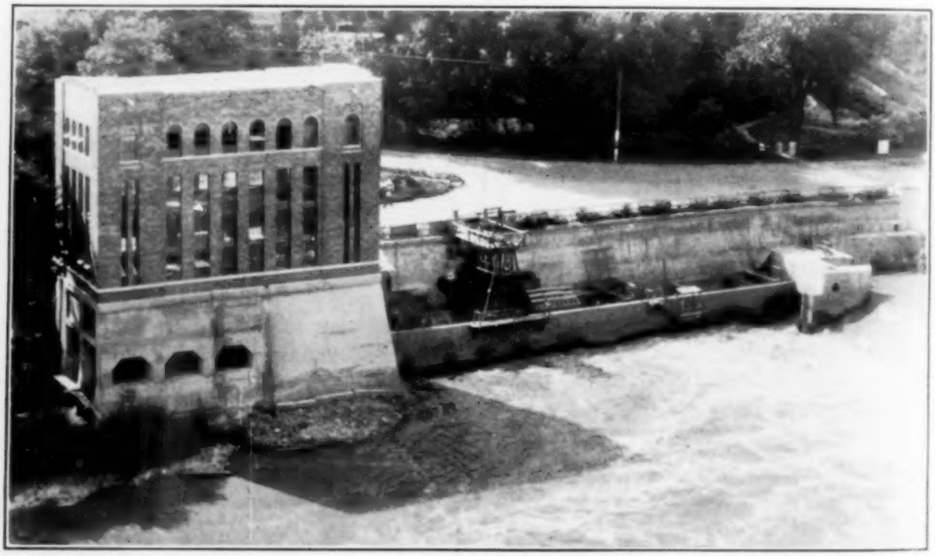
By Professor SHERMAN M. WOODWARD

HEAD OF THE DEPARTMENT OF MECHANICS AND HYDRAULICS, COLLEGE OF ENGINEERING, THE STATE UNIVERSITY OF IOWA

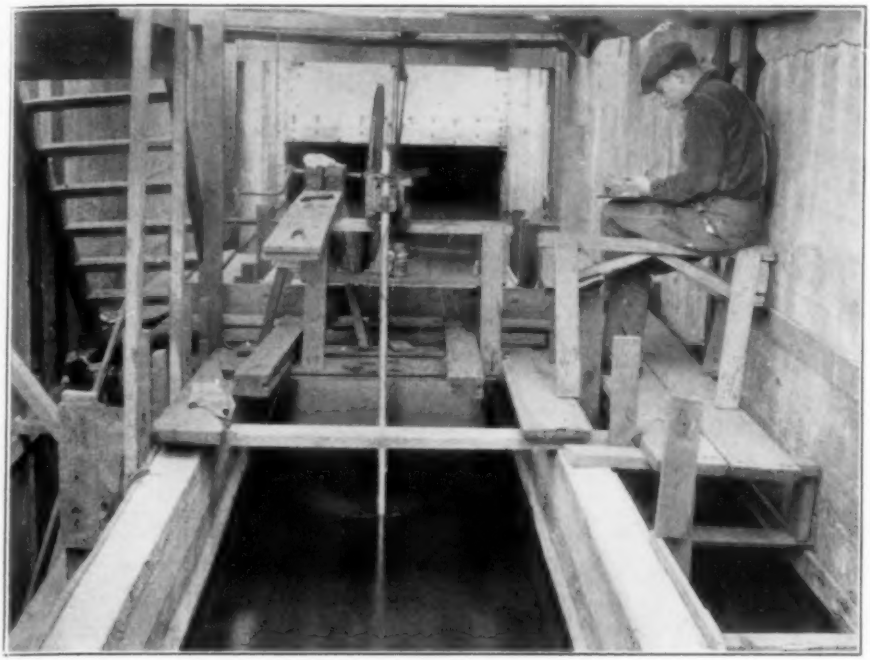
INTEREST in hydraulic experimentation has increased remarkably during the last few years. This development has been stimulated by the efforts of the engineering profession to persuade Congress to establish a national hydraulic laboratory, and doubtless largely also by the publication by the American Society of Mechanical Engineers of the monumental volume compiled by John R. Freeman entitled "Hydraulic Laboratory Practice," devoted chiefly to a description of the work of the numerous hydraulic laboratories in Europe.

Iowa University, because of its picturesque location on both banks of the Iowa River, a stream three hundred feet wide with an average flow of over one thousand cubic feet per second, is in a peculiarly advantageous position to undertake the experimental solution of a great variety of hydraulic problems. Through the generosity of a friendly donor, the university owns the water-power produced by a dam, nine feet high, across the river in front of the campus.

At the east end of the dam is a hydro-electric plant, which may be used when desired for experimental purposes but which is ordinarily used to furnish power for general university use. At the west end of the dam is a research hydraulic laboratory arranged so that as large a flow of running water as may be needed in experimental investigations may be used, up to the whole flow of the river.



HYDRAULIC LABORATORY AT IOWA UNIVERSITY



STUDYING THE EFFECT OF TURBULENCE
ON THE REGISTRATION OF CURRENT METERS.

The advantage of having available such a large supply of running water without the necessity of pumping it is of tremendous practical assistance in performing large-scale experiments. The head under which this large stream can be used is, of course, limited to the height of the dam. For experiments requiring a higher head it is necessary to pump the water used.

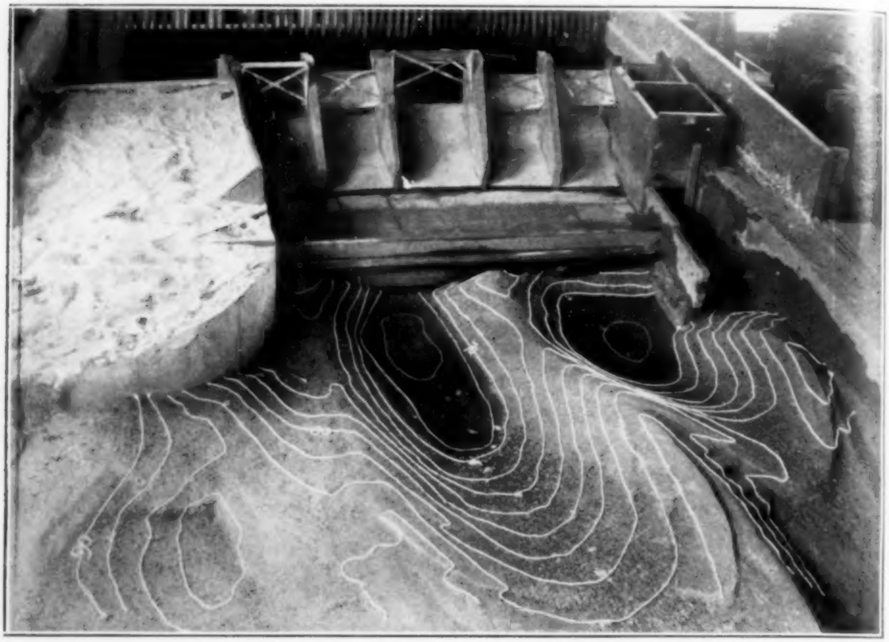
The hydraulic laboratory includes two main features. First, a straight concrete canal, ten feet wide and ten feet deep, about two hundred feet long, located along the river bank parallel to the thread of the river. This canal receives its water-supply through a large head gate in the end of the dam, and discharges its waters back into the river at its lower end.

Second, over the lower end of the canal, a building sixty feet long, thirty feet wide and four stories high. In this building are located offices, pumps, tanks, scales, piping and miscellaneous experimental equipment.

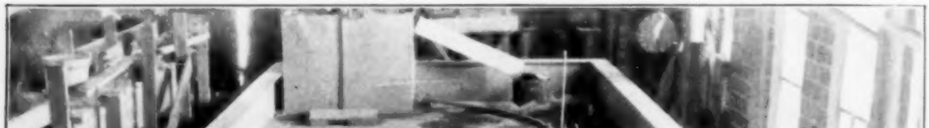
The growing demand for river improvements for flood protection, water storage, navigation, irrigation and water-power, coupled with the rapid evolution of various types of hydraulic machinery, has produced so many problems requiring laboratory research for their solution that the recently enlarged hydraulic laboratory at Iowa University has not been able to satisfy all the requests for the use of its unique facilities in this line. Some of the more important of the investigations that have been undertaken will be described briefly.

Flow Through Culverts

An elaborate series of measurements of flow through pipe culverts up to thirty-six inches in diameter and through box culverts up to four feet by



METHODS OF PREVENTING EROSION BELOW DAMS
Model of a dam with apron.



MODEL OF A SECTION OF THE DES MOINES RIVER AT OTTUMWA, IOWA
Looking up stream.

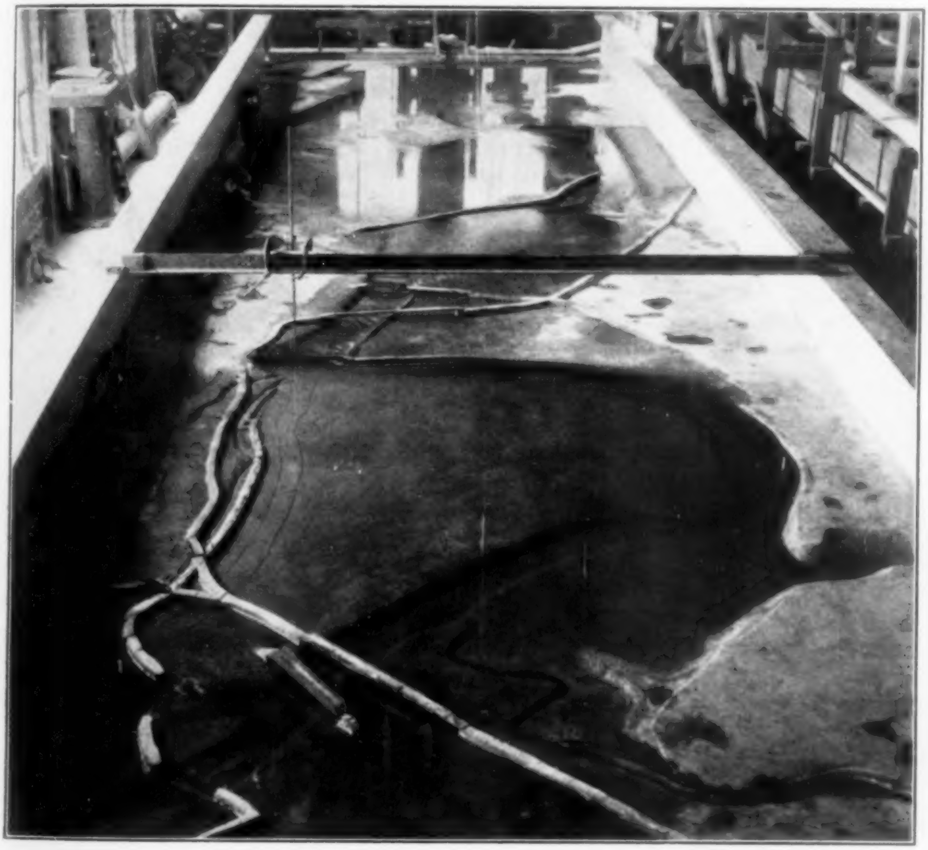
four feet in cross section was carried out for the U. S. Bureau of Public Roads by D. L. Yarnell. Friction losses for culverts made of corrugated iron, vitrified clay and concrete were determined, and the discharging capacities of culverts of different sizes were determined for various conditions. The results of these tests are now being used by highway engineers in developing improved highways all over this country.

Effect of Turbulence on the Registration of Current Meters

Current meters are so universally used in stream gauging that there has been much discussion of their accuracy under the variable conditions encountered in practical use. In this investigation a number of meters of different types were observed under controlled conditions simulating abnormal situations that sometimes occur. It was established that different types of meter evince entirely distinct tendencies to error in registration under such conditions.

Flow Around Bends

Most of the difficulties encountered by the hydraulic engineer arise from the fact that water must be made to flow along curved paths. An elaborate series of experiments was undertaken to deter-



THE FLOOD OF JUNE 1, 1903

One hundred thousand cubic feet per second, reproduced on model of Des Moines River without cut-offs.

MODEL OF THE DES MOINES RIVER WITHOUT CUT-OFFS
LOOKING DOWN STREAM.

mine the changes that take place in a stream of water having a constant cross section when flowing around a 180-degree bend. The pressure and velocity of the water were found to vary at different points to a surprising degree, and these changes follow definite laws, a knowledge of which can be applied usefully in a great variety of hydraulic machines and structures.

The Hydraulic Jump

Numerous experiments have been made on the hydraulic jump, both when stationary and moving, and in channels of various shapes.

Hydraulic Conditions at a Free Outlet

When water is discharged from a pipe, flowing full, into the air with a free fall at the outlet, rather surprising changes take place in the pressure and velocity distribution within the pipe close to the outlet end. Numerous experiments have been carried out to determine the laws that apply to these phenomena.

Weir Experiments

Various questions have been studied relating to factors determining or modifying weir coefficients.

Backwater Suppressors or Head Increasers

Whenever a flood occurs on a stream, all the water-power plants suffer from a loss of head at the plant. In low head plants this is often so serious as to cause

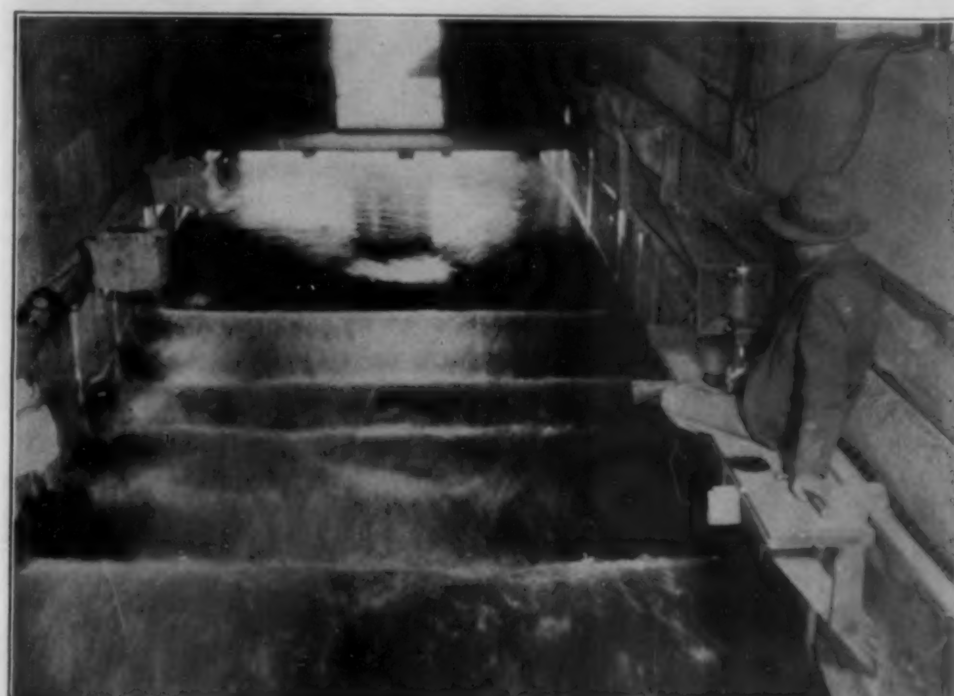
the plant to shut down during the continuance of the flood. Experiments have been made on various suggested methods and devices for turning the flood flow into a help to the power plant instead of a harm.

Calibration of the Keokuk Spillways

In times of flood in the Mississippi River, the amount of the flow is estimated by using the spillway gates on the dam across the river at Keokuk, Iowa. These gates are of so large a size that no similar openings had ever before been carefully rated. In cooperation with the Mississippi River Power Company the discharge through the spillway openings was carefully measured, after which a small model one eleventh the size of the spillways was constructed in the hydraulic laboratory. It was found that the flow through the model corresponded as closely as could be measured with the flow through the full-sized structure. This proves the great value of a small hydraulic model for predicting the operation of a full-sized structure.

Erosion Below Dams

Whenever flood flow has to be carried over or through a dam across a stream, there is danger of a serious erosion of the stream bed below the dam. This menace to the dam is greatest with dams built on a soft foundation, such as clay, sand or gravel, where a solid rock foundation is not available. We have experimented with several devices for destroying the energy of the rapidly



FLOW ACROSS DOUBLE-TRACK RAILROAD EMBANKMENT

Fifty cubic feet per second flowing over a ten-foot section of full-sized embankment. Depth on upstream rail 1.3 feet.

MEASURING THE OBSTRUCTION

TO FLOW OF WATER CAUSED BY PILE TRESTLES. THIS VIEW SHOWS A FULL-SIZED SECTION OF A RAILROAD PILE TRESTLE BENT. FIFTY-SIX CUBIC FEET PER SECOND FLOWING PAST PILE BENT.

flowing water and for protecting the bed of the stream from dangerous erosion.

Flood Protection for Ottumwa, Iowa

At the request of the city officials, there was constructed in the hydraulic laboratory a small-scale model of a stretch of the Des Moines River about three miles long through the City of Ottumwa. On this model experiments were made to determine the effect of various cut-offs in the river channel in reducing flood heights and dangerous erosion. The results obtained proved highly satisfactory and are being used in planning protective improvements that will cost upwards of a million dollars.

Diverting Flood Water Across a Canal

Where flood water was doing much damage on account of an inadequate outlet, it was proposed to divert the flood water across a canal into a river.

FULL-SIZED TEST SECTION
OF DOUBLE-TRACK RAILROAD EMBANKMENT TEN FEET IN LENGTH.

At the request of the U. S. army engineers, laboratory models of various types of gate structures were made and tested until a satisfactory type was developed. In this manner at a cost of only one per cent. of the completed structure, it was possible to compare a number of quite different types of proposed devices and to select the one most suitable.

Flow Through Gates

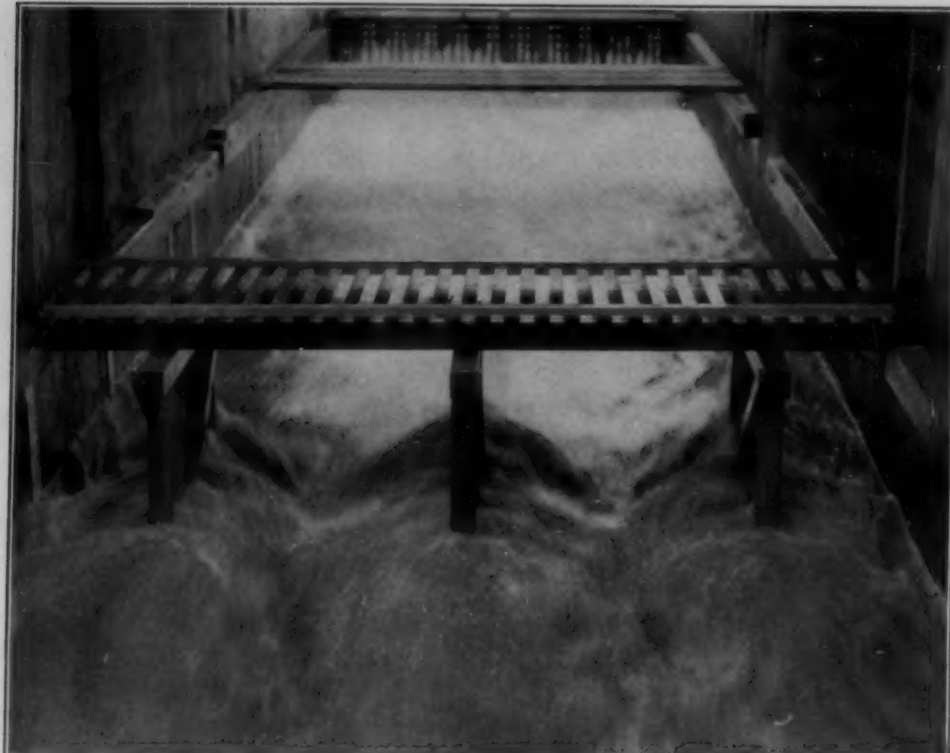
In some important titles to water rights and contracts regarding flow through gates, dating back over a hundred years, it was found to be practicable to duplicate in the laboratory the original gates and to calibrate them for all openings.

Flow Across Highway and Railway Embankments

During high floods it frequently happens that a part of the flood discharge

FULL-SIZED TEST SECTION
OF HIGHWAY EMBANKMENT, TEN FEET LONG WITH TWENTY-THREE-FOOT CROWN.

FULL-SIZED TEST SECTION
OF HIGHWAY EMBANKMENT, TEN FEET LONG WITH A TWELVE-FOOT CROWN.



MEASURING OBSTRUCTION OF PILE TRESTLES
TO THE FLOW OF WATER. PILE TRESTLE BUILT TO ONE FOURTH SIZE OF TRESTLE. THIS MODEL REPRESENTS A PILE TRESTLE FORTY FEET LONG.

flows across embankments that have been constructed for highways and railroads. In order that flood protection works may be intelligently designed, it is necessary to estimate the amount of past flood discharges. For this purpose a knowledge of the rules and coefficients for flow over embankments is essential. To obtain such information short sections, ten feet long, of full-sized highway, and both single track and double track railway embankments, were constructed in the experimental canal; the amount of water which could flow across these embankments at different depths was then measured.

Bridge Piers

For generations past the amount of the obstructive effect of bridge piers in interfering with the flow of streams has been a subject of debate. Many experiments have been made in the laboratory on models of bridge piers of various shapes and sizes to determine the degree to which they retard the flow in the channel. At the same time careful studies have been carried on to determine the effect of the piers in producing disturbances in the flow of the water by which erosion of the bed and banks of the channel may at times be dangerously increased.

Flow Through Trestles

Trestle bridges are still much used for both highways and railways. Their effects on flood heights is a live question on which information has been almost entirely lacking. Extensive experiments to throw light on this subject have been recently carried out.

All this hydraulic laboratory research at Iowa University has been under the general direction of Professor F. A. Nagler.

The different problems that have been enumerated cover a wide range. Some relate to the fundamental laws of hydraulic science, problems through whose solution we may hope to advance the whole field of hydraulic engineering. Others deal with the reliable determination of experimental coefficients, giving data of definite practical value in the ordinary daily work of the engineer. Still others, such as the reduced-scale models of proposed construction, may be chiefly valuable in connection with a single location. They are most useful in trying out varying proportions and devices, in directions that are not subject to theoretical computations. They also are of great use in demonstrating how a completed structure will look and act and so are of invaluable assistance in helping to decide between different proposed types of device. In our experience a study of a model costing not over one per cent. of the cost of the full-sized structure has saved many times the cost of the study by securing the most effective and economical design for the need to be met. To limit progress in hydraulic engineering to such as can be accomplished through critical and experimental study of full-sized structures after they have been built is too slow a method for present-day needs. A most elementary experience in testing models of hydraulic structures will quickly demonstrate that often a surprising—almost wonderful—improvement in their design for the purpose of securing some wished-for results can be obtained by modifying the original design by changes that are quickly and economically worked out by changes in the model.

Hydraulic engineering is made interesting by the fact that the solutions of its problems can never become standardized. Every project in hydraulic construction presents its own peculiarities in situation and conditions, peculiarities requiring individual solution. Probably this fact has contributed largely to the great expansion of interest in the building of hydraulic laboratories in recent years. Additional facilities in this line will apparently continue to be needed for years to come.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

CRYSTALS

By Sir WILLIAM BRAGG

DIRECTOR OF THE ROYAL INSTITUTION, GREAT BRITAIN

I HAVE found it rather difficult to choose a title for this short talk. At one time I thought of calling it "diamonds" because the diamond is the king of crystals. But when diamonds are mentioned every one is apt to be thrilled rather with their extraordinary value in money than with any other characteristic. And that is not at all what I want to talk about. There is that in diamonds and all crystals which is much more wonderful than the curious fascination which they exert on lovers of jewels.

First of all let me remind you that crystals take on innumerable forms. Diamonds and rubies and other precious stones are recognized as crystals by every one. We have all seen crystals of snow and ice, of sugar and of salt. Most people have picked up crystals of quartz or rock-crystal, and wondered at their clearness, at the perfect flatness of the faces and the sharpness of the edges. Of course, a drug-store or a chemical laboratory is full of crystals of many kinds.

Those who work in metal find that all their materials are crystalline in character more or less—and indeed the crystals in a metal can often be seen by the naked eye. The strength of a piece of metal depends very directly on the size and number of the crystals which it contains. The break-down of a metal structure is sometimes due to the fact that the small crystals are apt to grow into large ones, especially when there is much vibration; and that makes for weakness.

When we begin to look more closely at the things about us we find crystals everywhere, and I must tell you in a moment how this is done. Even our bodies are partly crystalline: there are crystals in bones and teeth. Still more surprising is the fact that there are crystals in hair and wool, in cotton and silk and rubber. In fact, there are crystals or something approaching thereto in all the things about us. And the strange fact is that this crystalline form, though it be generally unobservable by the eye, is of first-rate importance to the behavior of substances, to the part which they play in nature and to the use we men make of them. Consequently it becomes important both for the sake of pure science and for the sake of industry to find out what this crystalline structure really is and what we can do with it.

Now in recent years we have been fortunate enough to discover a means of looking into the nature of things more closely than ever before. We use the X-rays. It is not very difficult to get a general idea of the way in which the X-rays can do for us what ordinary light can not. The fact is that X-rays are also a form of light; they are of the same nature as light but of a very different quality. They are far finer in texture. The use of radio transmission has made us more or less familiar with wave-lengths in the ether; waves of a few hundred meters or yards are commonly employed. Light also consists of waves in the ether, but they are about

a thousand million times shorter than the waves of radio transmission. The eyes of living creatures are so made that they can detect these waves, and in doing so, are able to see. They can not see wireless waves; neither can they see X-rays, the waves which are ten thousand times shorter even than the waves of light. Thus we get the idea of a wide range of quality in these waves, but only a small range affects the eye and can properly be called light. Our eyes may be likened to a radio set which can only take in waves within a certain narrow range of frequencies. The vision of some people is still more limited than that of the average person. We say that such people are color blind.

What should we see if our eyes could take in a wider range? We should have new colors presumably, of which we can no more form an idea than a man who is color blind to red can imagine what red is like.

One thing only we can be sure about: the shorter the wave-length the finer the detail that can be observed. Small things want small waves to show them up. One can get some kind of parallel effect in radio itself. The long waves that are used swing round hills and buildings, so that the listener can often hear though a straight line can not be drawn from the receiver to the source without passing through solid masses; hearing may not always be so good but it is generally there.

Now light waves would be of no use if they behaved like that. If they did we should swim in a sea of light but it would be much the same in all directions. Whichever way we looked we should be receiving light from all the surrounding objects; we should have to exercise care even to sort out whether a thing was in front of us or behind. We must have light that turns corners as little as possible. Even in radio transmission when a so-called "beam" is wanted—a ray which will keep more or less straight without spreading—short waves of twenty or thirty meters only are employed. Now small details can be kept distinct only when the rays of light from them keep very straight. For this reason there is a limit to the smallness of things that may be seen by the aid of ordinary light; not even with the aid of the microscope can that limit be overstepped. In the same way it might be possible to detect the presence of a mountain by its effect on radio transmission; but radio could not be used to find a house or a tree.

But the X-rays enable us to see, if I may use the word, what light can not show us. Of course, we have to replace our eyes by specially made instruments. And when we use the X-rays we find ourselves in a new world which is always about us, which has to do with the structures of ourselves and all our surroundings and with the way in which those structures are fitted for their work. This new world has hitherto been hidden from us.

First of all, we are struck with the constant tendency in nature to arrange in order the atoms of which all things are made. The carbon atoms which make up the diamond are arranged in a beautifully simple pattern, one of the most regular of all the patterns we find in crystals; and no doubt we have here the reason why the diamond is so hard. When it is rubbed against other substances in which the forces that tie the atoms together are less strongly and systematically combined, it is the atoms of the second substance that must shift, while the diamond remains unchanged.

With the aid of the X-rays we can peer down into the pattern of the ice crystal, so fine in detail as to be far beyond the power of light to examine, and we see the atoms of oxygen and hydrogen arranging themselves to make six-sided figures which, when multiplied

enormously, make the crystals of snow and ice with which we are familiar.

There is a certain pattern, requiring only a few atoms of carbon, oxygen and hydrogen, of which nature makes wide use in all plant life; all plants contain tiny crystals formed by repeating this pattern. We are beginning to understand the structure of this unique substance called cellulose, which is obviously of first-rate importance to every living thing that is rooted in the ground.

There is a certain way which carbon atoms have of stringing themselves out into long chains with special little groups at each end. Of these also we begin to see and measure the details, and get a first idea of how their structure affects their properties. These are the fats and oils, alcohols and paraffins. And so on.

It is easy to understand why the crystal form is now being so eagerly studied. From the purely scientific point of view the research is fascinating, while on the industrial side every one who handles materials containing crystals, and that is a wide range, metals and stones, hair and wool, cotton and rubber and paints, and a host of other things, finds that the behavior of what he handles depends always to some extent, sometimes to a large extent, on the crystals which it contains.

THE PAST AS LIVING

By Dr. JOHN C. MERRIAM

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The words past, present and future have such definite significance that it is difficult to conceive of anything which could change their meaning. The present is living, the past is dead and the future unknowable. But, in reality, our appreciation of these things in individual day-to-day life is based upon narrowly limited experience. This may be illustrated by what is found if you have opportunity to take a great telescope and look out over the heavens. The astronomer will tell you that the stars and other objects examined are so far away that we do not see them as they really are at this moment. Although light travels with enormous speed, the rays bringing the image of these heavenly bodies to our eyes require a little less than two seconds to come from the moon, eight minutes from the sun, about four years from the nearest star and more than one hundred million years from the farthest objects thus far known in the universe.

So, in reality, we observe the stars and planets arranged not only according to their position in space, but with reference also to different stages in time. The nearest objects correspond as it were to yesterday; the farthest we see are, as it were, living and functioning in the age of dinosaurs. In terms of history of the earth, they correspond to a time before the Rocky Mountains were formed. Moreover we see all these things as fully real, and in operation at the same moment, though in different places and different ages.

In a recent speech I told this story of the various stages of time as all seen at once in the heavens, and in making the statement I remarked that these relative times depend upon both position in space and rate of communicating vibrations as represented by light-waves. One of my hearers remarked afterward that while I was speaking the transmission apparatus on the desk before me was broadcasting the talk throughout

the city and country, and that since no amplifiers were provided for the auditorium I was probably heard in the surrounding region before the sound reached the auditors at the back of the room. The hall was of considerable length, and the speech was being carried only by relatively *slow* moving sound within the room, but by rapidly moving radio waves outside. If, as my friend believed, the outside country was aware of each word earlier than the listeners at the rear of the auditorium, then the observing of what was happening there had a relation the reverse of that described for the stars in heaven. The more remote places in space were nearer in time than those close by.

When, as in the illustrations given, one begins to recognize past and present as if together, the barriers cutting off the past seem less formidable. Time appears then as a larger place in which to move about, and the past, which has been counted as dead, comes into consideration along with the present.

The relation of time to space as we now see it gives a changed appreciation of what the past may mean. But there are two other views of corresponding importance, both of which are naturally linked with the first. One relates to the living aspect of the past; the other concerns the unbroken or continuous nature of events through past and present.

But, in spite of all one may say, it is true that in average human life the past is something that appears relatively valueless. We say the past can not be *changed*—the future *can* be moulded. Let the dead past bury its dead—turn to the living future. And so I believe we *should* view the situation, unless the past is seen to live. But the instant the past takes on reality, it seems almost to become a part of our lives to-day. It certainly becomes one of the most important elements in moulding the future. It is largely regarding this point that I am speaking.

In general the more remote a thing seems in time the less its reality, and with this goes naturally the assumption of its relatively sharp separation from anything concerning our personal lives. But it is upon the vitality of the thing in the past that our interest depends. Though fading into dust, the flower we find upon the coffin of an ancient king stirs again the springs of human tears, as when placed there long ago it symbolized a last caressing touch.

Recently in a great ruin in the Southwest I examined the dwellings of an ancient race that lived at Mesa Verde. The beautifully constructed dwellings, in caves high up on the canyon wall, made one realize the presence there of many generations that struggled with the peculiar problems of that arid region.

In one room of these buildings the smooth covering of mud, plastered upon the wall, had fallen away. Examining the texture of the material I noticed that the lower coating was marked with innumerable prints of fingers. The first masses of clay had been pressed carefully into the spaces between the stones. The marking of each finger, every joint and corrugation had been left on the surface. This work was not merely that of indefinite human beings of ancient time. It represented an individual man, who doubtless bore a name, had friends, perhaps also a family. Whether this was his home or only a place in which he shared the comforts and protection of the community we may never know. I trust that when this particular piece of work was finished, he was cheered by having some one say to him, "This looks good to me."

Not far from these cliff dwellings I stopped at a trading post to buy some Hopi Indian pottery. The manager, a man with an inquiring mind, showed me a slab of rock from a nearby quarry, and upon it a peculiar impression. The Indians had called attention to the fact

that in this solid rock were many "cattle tracks." Some of the trails crossed the rock and excavation showed them continuing into the hill. The Indian knows "real tracks" from "might be tracks." He had no doubt about these particular ones. In the same formation are many skeletons, but cattle do not appear among them. The great bulk of the remains are ancient American camels, which also have cloven hoofs. These rocks belong to an age antedating the last great period of mountain making in America. Millions of years would be needed to give the measure of their remoteness in time. But over this arid landscape of to-day the Indian pointed out the trail of cloven hoofs in the rock.

As one travels over the earth, the wonders of these living pasts are multiplied, sometimes made known by science, sometimes by instinctive recognition of untutored students of nature such as the Indian. Always there is borne in upon one the inescapable reality of a vast stretch of time linked with the present.

Commonly the elements of the story as we find it are only isolated episodes. There are few places where one may see it illustrated in such a manner as to impress upon us the picture of its reality, continuity and scope. As nowhere else in the universe we find at the Grand Canyon of Arizona the evidence of moving events in the clear order of their occurrence, and so visualized that one sees, as it were, the panorama of history in operation. This story illustrates at least one thousand million years of action so presented that one may not mistake its meaning.

I have already stated that in looking out over the heavens we see many stages of time in different places. In the Grand Canyon we see a vastly longer stretch of time with all the steps or stages shown, as it were, in operation at one place and at the same moment.

In the vast wildernesses of the past, such as are encountered in the Grand Canyon region, one may explore with a sense of reality like that in the wild and unknown regions of the earth to-day. The shifting continents of ancient time —the changing seas—world after world of strange forests and creatures that exceed the weirdness of fiction—pass under the adventurer's eye. So fully aware is one of what they represent that they are no longer dead, but come into new life through a resurrection made real by the interpretation of science.

These elements of the world from past time illustrate the interlocking of events so that all appear as one story. In their continuity they also interpret in an extraordinary way the modes of operation in nature, which we call laws, operating in similar manner throughout time and space.

Once they are conceived as reality, and as expressing a continuous process, the past becomes the basis upon which the present and the future must be built.

Some years ago, a man whose conduct had been investigated, because he did not agree with others as to how public affairs should be conducted, was reported to say that, considering his recent experiences, he would be happy if he could be "as sure of his past as he was of what he would do in the future." In this instance, the future was improved by study of the past. So with reference to the story of life as a whole. It is the longer reach of acquaintance with history that gives us the best guide for the future. We may not change the past, but we may build upon it. We may not wholly determine the future but we may mould it according to what we learn from the past. Those are wisest who build upon the longest experience extended into the farthest reaches of the future.

The tendency of modern science to

consider the relation between time and space—or, in another sense, to disregard what have seemed to be barriers in space and time—has made possible some of our greatest advances in knowledge. But this broad-mindedness is not found only in science. It has expressed itself in business, where more and more great projects not only look forward to a more distant future, but build themselves upon the broad foundations of long experience.

Not only does wisdom indicate our need of knowledge for the whole of space and time. It also is clear that no generation may live to itself alone. There may be no higher degree of selfishness than that of any generation which disregards both the future and the past and denies to those who have made sacrifice the right of the continuing influence of their accomplishment.

So, as an illustration, it is a part of our duty to-day to guarantee that the poppies that grow in Flanders shall represent a widening circle of influence from lives that have not been lived in vain.

LIGHT AND THE GREEN PLANT

By Dr. JOHN M. ARTHUR

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THE present state of our knowledge regarding the nature of light is well expressed by the following dialogue:

"What is light, Mr. Staller?" asked the professor of freshman physics.

"I did know, but I have forgotten," replied the freshman.

"That is too bad! So far as I am aware, you are the only man who ever knew and now even you have forgotten!"

While we are uncertain as to the exact nature of light, in this modern age of reason we are naturally interested in finding out more about it, what its characteristics are, how we can measure it, what effects it has on plants and animals. No one doubts the supreme importance of light. Even primitive man must have been impressed with the importance of light to his continued existence. In the first chapter of Genesis light was the third act of creation. After orienting the heavens and the earth the next logical act of the creator was to put energy into the system, the energy of light.

Contemporary physicists think of light as radiant energy visible to the human eye. This includes the primary colors and all their various shades, red, orange, yellow, green, blue and violet, which can be separated from sunlight by means of a prism. The word "light," descriptive of the third act of creation, necessarily included the shorter rays not visible to the eye, the ultra-violet, X-rays and cosmic rays, since these are a part of the same system of radiant energy. The longer rays beyond the visible at the red end of the spectrum, the infra-red and radio waves, fit naturally into the same general scheme of radiant energy and were also originally included in the word "light." At the risk of being accused of inaccuracy in terminology we will use the term sunlight in the broadest sense to include all regions of radiant energy received from the sun.

Sunlight is the great source of energy upon the earth. Moonlight has been thought to exert some influence on the growth of plants, but on account of its exceedingly low energy value it has little or no effect on the process of photosynthesis—the process in which the green plant uses the energy of sunlight in the

synthesis of sugar, starch and cellulose. We naturally think of three main regions of sunlight: the infra-red or heat region; the visible region, including all the primary colors, and the ultra-violet region. We are interested in knowing whether these regions affect plants equally in proportion to their relative energy values. More than 50 per cent. of sunlight is in the infra-red. Green plants grown from seed under a dark glass or other filter which transmits only infra-red appear white, because of failure to develop the green pigment, chlorophyl. The plants will continue to grow until all the food material stored in the seed has been used, but they will weigh no more than similar plants grown in a dark room and will eventually die. This region of sunlight apparently has no value to plants other than a temperature effect. The energy absorbed aids in the evaporation of water and in increasing the temperature of soil and air.

The other extreme of sunlight, the ultra-violet region, has been found to be especially important in the life of the animal. The ultra-violet of sunlight which is not transmitted by ordinary window glass produces vitamin D, the vitamin which prevents rickets by inducing calcium fixation in the bone tissue of young animals. So far as has been determined, there is nothing comparable with this in the case of plants. Several species of flowering plants have been grown under a glass which transmits 80 per cent. at the extreme ultra-violet limit of sunlight and no differences have been observed in the growth habit, time and amount of flowering or amount of green tissue produced as compared with plants grown in an ordinary greenhouse. We have yet to find any distinct advantage to the plant in growing it under a glass which transmits the extreme ultra-violet region of sunlight. When plants are grown as food for animals, however, there is a possibility that some plants grown under a glass which transmits this region will contain more vitamin D than those grown under ordinary window glass.

On the other hand the ultra-violet of sunlight has not been found to be definitely injurious to plants. Experiments have shown that the short-wave ultra-violet produced by a mercury vapor arc lamp in quartz is very injurious. These rays will produce considerable injury on the leaves of tomato plants in an exposure of 30 seconds. It is interesting to note that this region is quite generally toxic to both plant and animal cells where it is absorbed. It is effective in killing bacteria and in killing the virus which produces the mosaic disease of tobacco, as well as producing violent sunburn on our own skin. Fortunately this destructive radiation in sunlight is absorbed by our atmosphere so that it does not reach the surface of the earth. The exposure time necessary to injure plant tissue increases rapidly with increasing wave-length, and it is believed that the ultra-violet limit for sunlight could not produce the typical ultra-violet injury upon plant leaves. It can not be pointed out too strongly, however, that one needs to overstep this extreme limit for sunlight by an extremely narrow margin to produce great injury upon plants.

The visible region of sunlight is most important in the unique process of green plants, photosynthesis. Approximately 45 per cent. of the total energy of sunlight is in the visible region. For this reason sunlight is a more efficient light source for growing plants than the ordinary Mazda lamp which has only 4 per cent. of its light output in the visible region. The energy of sunlight is absorbed by green leaves and used to build up carbon compounds such as starch, sugar, cellulose and wood out of carbon dioxide from the air and water from the soil. This process is not effi-

cient. It has been estimated that less than 1 per cent. of the total energy of sunlight falling upon the leaf is used. Yet inefficient as it is, this process is the ultimate and sole source of energy for our food and fuel supply.

Most of us unthinkingly regard sunlight as a more or less constant value. When we observe the brilliancy of a battery of electric flood lights the first question we ask is, "How does this compare with sunlight?"

The answer is, of course, that the lamps do not compare with sunlight. Electric lamps in general are infinitely more constant. Sunlight varies in both quality and intensity from minute to minute, day to day and season to season. Yet all these variations have limits and we realize that plants somehow manage to grow within these limits. We might conclude from this that plants are insensible to wide variations in light quality and intensity, or even that they will grow in about any quality or intensity. Only by exceeding the limits of intensity, quality and duration ranges of sunlight can one be convinced that, after all, the plant not only is not indifferent to these changes, but is attuned to some of them and is easily injured whenever the natural range is greatly exceeded in any direction.

In order to test some of the effects of light quality several species of plants were grown in a greenhouse covered with a red glass filter which transmits none of the blue region of sunlight. These plants very much resembled those grown in a dark basement except that the green pigment, chlorophyl, developed. The stems were very long and weak and the leaves were narrow and thin with a tendency to roll from the midrib towards the margin. Similar plants grown in another greenhouse covered with a blue glass which transmits no red were small plants, normal in appearance except considerably dwarfed. Neither the red nor the blue region of sunlight is sufficient to grow normal plants. Some light energy from both ends of the spectrum is required.

It is well known that in our latitude the length of day increases from the winter solstice in December to the summer solstice in June and then decreases again. Light intensity follows a similar seasonal increase and decrease. Average temperature shows a corresponding increase and decrease reaching a maximum and minimum, in general, a month or more later than corresponding points on the daylength and light intensity curves. That is, while the longest days of the year come in June in our latitude the highest average temperature occurs in July.

Likewise it is well known that certain plants flower only in the spring or fall. Others flower only during the summer, while a few plants flower continuously during the growing season. It is evident that plants are attuned to certain seasonal climatic factors as regards flowering. In order to study the effects of these factors it is important to be able to control all climatic factors and vary each one at will. Garner and Allard, working at the U. S. Department of Agriculture, showed that some plants which normally flower in the fall, such as the late cosmos, could be made to flower in early summer by exposing the plants to daylight from 9 A. M. until 4 P. M. each day. These plants were attuned to flower only on short days. At the Boyce Thompson Institute for Plant Research plants have been grown in an artificial climate using, in one case, daylight supplemented by artificial light each night and in another, all artificial light. Forty-eight 1,000-watt electric lamps of the ordinary incandescent type were used as a light source to supplement sunlight in the first case. These lamps were carried upon a crane which was moved over a greenhouse at night

and moved off again during the day so as to avoid shading. In the second case twenty-five 1,500-watt lamps were used as a light source in a basement room approximately 11 feet square. Temperature and humidity were accurately controlled by means of standard air-conditioning equipment and the carbon dioxide concentration of the air was closely regulated.

Many plants grow well in such an artificial climate. Red clover plants were grown from seed to flower in thirty-eight days, while the grains, spring wheat and barley, were grown from seed to flower in the same time period. While many plants grow well when illuminated continuously, certain plants, such as the tomato, require approximately a six-hour period of rest in a dark room each day. The length of day affects flowering whether sunlight or artificial light is used as a light source for growing plants. That is, long day plants such as lettuce and radish which normally flower in the early summer flower on daylengths greater than twelve hours. Everblooming types, represented in these experiments by buckwheat, flower on all daylengths from five hours to twenty-four, while the height of the plant increases regularly with daylength. Short day plants which normally flower in the fall, such as salvia and ragweed, flower on short days of twelve to fifteen hours or less. Many victims of hayfever in southern Illinois have no difficulty in recalling that they normally start to sneeze on or about August 15 each year when the ragweed comes into flower. These unfortunates are indirectly attuned to daylength.

When we are able to reproduce natural conditions in artificial climates more accurately we will no doubt find many other plants attuned to either one or a group of natural climatic factors which vary with the season. Such studies, we believe, will result in a more intelligent handling of plants. While we are at present mainly occupied in a study of some of the fundamental conditions associated with plant growth, we hope at the same time to remain alive to the possible application of our studies to the benefit of those of our own generation.

MENTAL HYGIENE

By Dr. WILLIAM A. WHITE

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THERE is nothing mysterious about mental hygiene except that we have always thought of the mind, when we have thought of it at all, in terms of our ignorance about it, and have felt that it was a great unknown territory. In fact the study of the mind, psychology, until recent years, was taught as a branch of philosophy. It is only within the present century that it has won a place for itself among the natural sciences, more particularly among the biological sciences or the sciences that treat of living beings.

I have said there is nothing mysterious about mental hygiene. We have long been familiar with the term "hygiene," and we have recognized its significance as an effort to live healthy lives, but we have thought of it in terms of our physical bodies and their function and not in terms of our minds. We have recognized that hygiene requires a reasonable amount of rest, a reasonable amount of exercise, good and properly selected food in adequate but not too great quantities, pure drinking water and a thousand

other things. But we have not recognized that all these, and many more, are really only means to an end, and that what man lives by really is not food and drink but ideas and ideals, desires and hopes, aspirations and ambitions, and these are matters of the mind. A recent book by a noted Italian on this general subject sets forth his objective in the following vigorous words:

> I write . . . to dislodge indifference to the momentous subject of eugenics, to lay open to the public conscience the dangers of bad habits and of certain defects of our present school system, to call attention to the responsibility of the government, to fan the fires of the inexhaustible energies of our race which now lie sleeping under the ashes of inertness, of ignorance and of old customs. I write for the invigoration of our spirits and for the discipline of our lives in health, in strength, in new religion, in beneficent liberty.

This is a rather ambitious program, but it is along the lines that I have suggested, for it deals not with the material needs of life but with the immaterial and more important things that we live by. Further than that, this program has other very specific references and indications. Man has never worked out a very adequate understanding of his mind. He has always accepted what he found there. People believe or doubt, they hope and they fear, but they rarely ask themselves why they believe or doubt, or why they hope or fear. These mental facts have been accepted and acted upon practically without any consciousness that they are subjects, or could be made subjects, of scientific inquiry. We are accustomed to apply our science only to concrete things which can be seen, to animals, to plants, to planets, to crystals—not to these intangible ideas which seem to escape us the moment we attempt to inquire into them. But man is a very ingenious animal. The possibilities of his inquiring mind are unknown but capable, without doubt, of very much greater development even than they now have. And so with that everlasting curiosity of his which has unearthed so many secrets of nature, he has now turned his attention to these intangible ideas. He has become for the first time profoundly interested in his own affairs. He is applying scientific methods to their study and elucidation, and he is beginning to insist that the great facts of science as they are discovered in all its various realms shall be made to point in his direction, that there shall be asked the question, "Of what value is this fact to me, how can I profit by it, how can mankind be improved by its application?"

The twentieth century has given birth to this great interest, which is rapidly and certainly gripping the imagination of peoples in all parts of the world, and man is applying his ingenuity in attempting to discover answers to the questions that have puzzled him for generations: Why do people become mentally ill? Why do they become criminals? What is the meaning of unhappiness and discontent? How can habits that are destructive be modified? How can the energies that are being poured into useless activities be recaptured for the common good?

Difficult as some of these questions may seem, unanswerable as they may appear, it is nevertheless true that we are moving in the direction of better and better solutions; that progress is being made, slowly perhaps, but, after the manner of science, with certainty; that the domain of false ideas and traditions, of superstitions and taboos, of nameless fears, of destructive tendencies—that the domain of these hobgoblins of the mind is being gradually invaded, that they are being studied with the purpose of their modification and ultimate conquest. Mental disease is beginning to give up its secrets. We are beginning to learn how to deal with problem children. We have already

glimpsed the problems which the criminal presents and have some idea of the direction in which to look for their solution. We have attacked the difficulties and maladjustments of the industrial world. And in a thousand and one ways we have made efforts to find out the laws which obtain in the sphere of the mind and which must be observed if one is to be mentally healthy. All these things and many more are of tremendous significance to every one, and it is the purpose of my few remarks to direct your attention to them, to invite your interest in this comparatively new field, for you will, I am sure, see unfolded in these various directions during the next generation facts of the utmost significance to the welfare of mankind.

Many of you who are listening to me will undoubtedly say to yourselves, "This is all very interesting but what application has it to me? I am not insane, I do not expect to become insane, there is no insanity in my family, my friends and acquaintances are all self-sustaining, mentally well individuals so far as I know. This whole matter is one only for the exceptional individual, who will be adequately cared for by the means that are provided by the state and a few private hospitals." If this is your conception of the significance of the problem of mental illness, may I say to you at once that you are quite wrong? To-day the number of beds in hospitals for mental disease throughout the United States is very nearly as great as the number of beds in all other types of hospitals combined; and a recent report shows that of the beds under construction there are actually more beds being built right now for mental diseases in the United States than for all other diseases put together. In other words, you are certainly occasionally sick, almost every one of you, and these figures would indicate that you have on the whole pretty nearly as much of a chance of being mentally sick as you have of being sick in any other way. Fortunately, this statement is not quite true, because while there are as many beds in mental hospitals as there are in all the others, the number of patients that pass through these beds is much less because the patients stay on an average very much longer in the mental hospitals than they do in the general hospitals. Nevertheless, when I tell you that the statistics recently compiled of New York State, which I may remind you contains approximately 10 per cent. of the population of the United States, show that of the residents of that state one person in every twenty-two over the age of fifteen spends a certain portion of his time in a hospital for mental disease during the course of a generation, you will begin to see the significance of mental disease and to realize that after all you individually may not be as immune as you have been wont to think.

Therefore, mental illness is not rare, it is not exceptional, it is not something which may not affect you individually or those whom you may love. No one is immune; and I have no doubt that many of your friends and many of the families the members of which you know could tell you of cases of mental illness which they know about or which are actually present in their own families, if they would. Let me add to this somewhat startling picture the fact that the number of patients in public institutions for the mentally ill has increased something like 300 per cent. in the last half century. This does not mean necessarily that mental disease itself has increased at any such rate. It is partly an expression of the increasing confidence of the public in the mental hospital. But it is nevertheless a somewhat alarming state of affairs, especially when I tell you that according to the statisticians we are due to keep up this rapid rate of increase for the next half century at

about the same pace that it has been occurring during the past fifty years. If you could visualize this adequately it would be translated first into the material things—hundreds of millions of dollars for hospitals, hundreds of millions of dollars for salaries and wages for personnel to take care of these sick people and hundreds of millions of dollars wasted because of the inefficiency and failure of earning capacity of these patients while ill. It would represent also a loss to society of the services of these thousands of individuals not only expressed in money but in the many other ways in which their services would have been rendered. Husband and wife are separated; parents and children are separated; households are broken up; families become dependent upon public charity, and in many other ways the loss on the material side is enormous. But think in addition what it means in suffering and death, in the failure to function adequately as caretakers and directors of the new generation represented by the children. Think what it means in terms of crime and anti-social conduct generally, of wasted and aborted effort in all sorts of directions.

Perhaps no one affliction of mankind is so far-reaching and so destructive in its results both to the individual and to society at large, and all these things affect you, my listeners, very directly. You are now paying a very large percentage of your taxes to take care of the mentally ill, in one form or another. You are subject to all sorts of regulations and restrictions which were made because there are some people who need to be controlled. You are subject to the contagion by suggestion of all sorts of aberrant ideas which may be on the road that leads to mental illness. You are in every conceivable way closely affected by this great menace, and it is for you to assist all who are making the effort to minimize the ill effects that flow from this source as far as possible, to assist the mental hygiene movement, which has as its ultimate goal the prevention of mental disease, to help secure the adequate care of those who are ill at the earliest possible moment so as to insure the greatest number of recoveries, and in every way to spread that knowledge of mental disorder and that desire for mental health which is calculated to counteract it. Just think of what has been accomplished with such a disease as typhoid fever, for example. During the past year, of eighty-one cities in the United States of over 100,000 population, five reported no deaths from typhoid fever during the year, whereas twenty-eight reported less than one death per 100,000. It is hardly to be expected that any such results as that can be even hoped for in the realm of mental disease, because in a very real way mental illness of one sort or another (and in this term I include what are ordinarily known as the neuroses as well as the more serious mental sicknesses), represents the price that we pay for being civilized, and the progress of civilization seems to be closely interrelated with this whole question of mental illness. But what we can do is to undertake to see that we do not have to pay too great a price. We can make a concerted effort to reduce the cost of the advantages of civilization, and there is every reason to believe that this cost can be very materially lessened. So I plead with you to join your interests with ours, to help wherever you have a chance.

CHEMICAL ATOMS AND SUPERATOMS[1]

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In a recent essay[2] the writer attempted to demonstrate that the atomic conception, when used in the sense of structural or functional units, is a tool universally employed. It became evident that the clear understanding of any problem involving the behavior of a system requires, first, an analysis to reveal and define the structural elements that are functioning which must of course be visualized or selected on a suitable scale; and second, the effective synthesis of these elements into a functioning whole. In developing this picture a serious gap was encountered in the field of colloid chemistry, which Wo. Ostwald has so effectively characterized as a world of neglected dimensions. The difficulty encountered here arises from the fact that the classical atom of chemistry is still a living conception, and that chemists are continually trying to solve the problems in this field by means of the older forms of this concept. Such efforts have yielded only fragmentary results. It seemed clear that if the atomic conception could be adapted to the problems of the colloidal field, many things would be facilitated.

The effort to extend the atomic conception in a fruitful form into the field of colloidal phenomena is justified by the fact that colloids in spite of the intensive investigation of the last few decades constitute the no man's land of physiology and medicine. The anatomists have pushed the boundaries of their knowledge of tissue structure and organization to great lengths and are reconstructing tissues in the form of plastic models in such perfection of detail that the actual processes of health and disease can be clearly visualized to the absolute limit of visible structural detail. There is no possibility, however, that the resolving power of the microscope can be increased to the point that the elaboration of the toxic products of metabolism of the tubercle bacillus, for instance, can be witnessed, or that the first effects of these products upon the tissue cells of the host may be traced. The limits of the microscope are determined by the nature of light, and so these problems necessarily fall back into the field of chemistry, however much we may regret it, because—and we might as well admit it—although the limitations imposed by the microscope are great, those existing in chemistry are infinitely greater. It therefore becomes an urgent duty for chemists to reconnoiter the no man's land lying between and in front of the organized forces of classical chemistry and those of visible morphology in order to make contact between the two forms of attack. It is in this area that the next great advance in the conquest of life and death will be made. The battle-field lies ready; what is lacking is a general with a suitable plan of battle. While waiting for the great leader there is no objection to carrying on with exploratory raids, and this paper constitutes a report on such a raid.

The effort here described is in the nature of an exploratory reconnaissance. We wish to attempt to blaze an atomic trail across and through this colloid wilderness. Entering the woods on the chemical side, we hope to come out in the field of general biology. Such a trail

[1] In this paper only the most familiar types of chemical facts and concepts are used. For this reason in order to keep the story moving the author has failed to give references to the specific sources of information or views.

[2] Scientific Monthly, 29: 363–8, October, 1929.

would then constitute a temporary highway upon which workers in the field of chemistry and general physiology could maintain contact in their further explorations and developments of this world.

Since this reconnaissance is to move out from the chemical side and is to depend on the use of the atomic conception as a means of transport, it will perhaps clarify the situation to review the present status of the classical chemical atom.

Originally the term atom by definition involved the conception of indivisibility. When the spontaneous decomposition of the radioactive elements was discovered, this classical atom passed out of existence. An atom then had to be conceived as an elementary substance which might or might not be relatively stable. The views on atomic structure in process of development at present represent the chemical atom as a more or less complicated micro-astronomical system, which is composed of several or many discrete parts and which may or may not be relatively stable. The decomposition of a neutral atom may involve a simple reversible change like the loss or gain of one or a few electrons; or it may represent a profound disruptive change involving the formation of new chemical elements. The former change is characteristic for all chemically active elements, and varies as a periodic function of the atomic weights. It is analogous to the loss or gain of hydrogen atoms by a petroleum hydrocarbon. The latter change appears strikingly with the heavy radioactive elements and is analogous to the disruptive "cracking" of heavy petroleum hydrocarbons. In the former, we have a periodic recurrence of similar properties with gradually increasing atomic weights. In the latter, we have an innate instability associated especially with high atomic weights. This gives rise to a progressive decomposition in which energy or energy and helium atoms are lost. This disruption into simpler atoms is associated with the highest atomic weights. So much information has already been accumulated concerning such transmutations that it appears possible that helium is constituted of residues of four hydrogen atoms and that the remaining elements represent complexes derived from these hydrogen and helium units. Viewed in this way, we may conceive of the atomic series as being a series of structural units, each capable of acting as a unit, but composed in turn of simpler units coupled up in stable configurations which develop enough structural weakness in the higher members to undergo a controlled and gradual but spontaneous decomposition.

It is against this background of highly complex but perfectly organized atomic structures that the series of superatomic structures to be described in this paper is to be projected. Although the classical chemical atom no longer exists, the term has been retained and has taken on a new and definite meaning that seems to be accurately suited to the extensions to be developed. Its present meaning is indeed that of structural or functional units, which in turn possess an inner structural complexity of their own. Moreover, by retaining the word, we may hope to carry over into the realm of superatoms some of the time-proved traditions of thought and action of the field of chemistry. This would be particularly desirable if by their disciplinary effect they might become as fruitful in a general way in the future as they have been in a special way in the past.

Our problem then in this essay is that of finding superatoms of suitable dimensions so that we may construct a more or less continuous series from the traditional chemical atoms, through the field of colloids, to the field of visible morphological elements in the organism. In this program, it will of course be neces-

sary to learn to what extent and how chemical elements and compounds build themselves up into more and more complex edifices, which, however, still retain the essential characteristics of structural units capable of acting as a whole in chemical reactions of a higher order.

The idea that aggregates of atoms may function like a single atom in building up complexes was established by Gay-Lussac and later by Liebig in his classical work on benzoic acid in which he found the benzoyl radical acting like a monovalent atom. Very quickly these observations were extended and the interesting classical radical theory of organic chemistry was developed.[3] Later it was found that these radicals, unlike atoms as then conceived, could be attacked. This led to a modification of views and a decline of interest in this conception. Because of the influence of the classical conception of the unassailability of the atom, it seemed that an error in consistency had been made and the relation of atoms to radicals was no longer emphasized. However, this situation no longer exists, and the atom and the chemical radical are now closer together and more integrally related than they have ever been. This will appear more clearly in what follows.

In the meantime, it had become clear that in inorganic chemistry certain acid groups, such as sulphate, phosphate, nitrate, carbonate, silicate, etc., enter reaction as unified radicals. This seems to have been expected because of the associated idea, prevalent at that time, that oxygen is indispensable in acids, and consequently the idea that acid radicals that do not contain oxygen can exist was only slowly elaborated.

In the case of bases, the situation was somewhat different, and when it eventually became clear that ammonia acting as ammonium was able to play the rôle of an alkali metal even to the extent of forming amalgams with mercury interest was aroused from another angle. Gradually the transition from simple diatomic acids like hydrogen chloride to complex organic and inorganic acids and from simple bases like sodium hydroxide to the most complex alkaloidal bases was established and clearly interpreted. The continuity of these series was recognized, and the theory of electrolytic dissociation was found to be applicable to all of them, but it was not so clearly perceived that, since the chemical radicals in the higher members of the series functioned like the atoms in the lower members, they might be regarded as atoms of a kind. The radical concept replaces the atomic concept in these series as one passes from the simpler members to the more complex. Logically there is no break in passing from the atom to the most complex compound radical in these series. These radicals may therefore be regarded as an ascending series of atoms of increasing complexity.[4]

[3] "That the radical behaved like an element, had been confirmed over and over again. Not only did it enter into combinations with elements, but it could also be isolated from these combinations. How far this comparison was carried is shown by a quotation taken from a joint paper by Dumas and Liebig: 'Organic chemistry possesses its own particular elements, which sometimes play the part taken by chlorine and oxygen in inorganic chemistry; sometimes, on the other hand, the part of the metals. Cyanogen, amide, benzoyl, the radicals of ammonia, of fatty bodies, of alcohols, and analogous bodies; these are the real elements with which organic chemistry operates, and not the ultimate elements, carbon, hydrogen, oxygen and nitrogen, which only appear when every trace of organic origin has disappeared. It will thus be understood that the atoms which constituted such a group were supposed to be held together by stronger forces than those which united the group to other atoms.'" A. Ladenburg, "Lectures on the History of the Development of Chemistry since the Time of Lavoisier," p. 128–9, University of Chicago Press, 1906.

[4] Throughout this paper no effort is made to distinguish between neutral superatoms and charged superions. At this stage, it would

As investigation was broadened, it became increasingly evident that under suitable conditions certain metallic atoms, which customarily acted in simple ways as ions, were able to enter into very complex relations with other substances. Among these were conspicuous at first the various ammoniated derivatives of cobaltic and nickelic salts as well as platinum salts. Eventually illuminating clarification in this field was brought by Alfred Werner, by the development of his spatial conceptions regarding complexes of this type. Many obscure facts and relations were clarified by his fruitful ideas. Hundreds of other examples were subsequently discovered and described.

The main fact in all this for our purposes is that several metallic elements are able to associate with themselves molecules of certain chemical substances and to organize these in such a way that the whole system behaves in many respects like a single atom. These systems are conceived of as arranged in a geometrical pattern or shell around the central atom, and have no existence except through the coordinating or organizing influence of this central atom.

Such a complex structure is often very stable, contrary perhaps to expectations, and in some cases renders a compound more stable than it would be in the free state. Thus, for instance, the heavy metal nitrites, which are notoriously unstable in the free state, are readily obtained as stable complexes with hexamethylenetetramine and some other organic bases.

Many organic compounds enter into complex relations in other ways. Among the most familiar are the complexes formed by cupric hydroxide with various hydroxy acids used in the analysis of reducing sugars. The same is true for the colors developed with the Biuret reagent with proteins and many of their derived products. In fact, a very large number of color reactions depend upon the formation of a definitely organized complex. Many of the complexes formed have not been isolated and studied, while the nature of many others is still unknown for various reasons.

In many of the types and cases of chemical radicals that have been reviewed above, the complex enters into reaction like a simple ion—either acid or basic—and from this standpoint could be mistaken for such if its complexity were not revealed in other ways. But the same statement can be made about the chemical atom. It was and can be mistaken for a simple indivisible structure unless and until its complexity is revealed. Chemical radicals and chemicals atoms then have this in common, that they are both complex organizations that can and do function as a unit.

This unity of structure and function, even in the range of the atomic structures under consideration, is not, however, as simple as it might appear. The problem is complicated by the relations existing between solvent and solute. Consequently in any attempt to enter the field of biology with the tool kit of a chemist, we must sooner or later take account of water and its relations to materials immersed or dissolved in it. Water is the *sine qua non* for life, although in most considerations of vital processes it is regarded as a medium which is passive or at least relatively inert. It would, therefore, be unwise to attempt to avoid considering the relations of water to the atomic systems under discussion in spite of the difficulties involved in the subject.

In all our previous discussion, the presence and actions of water have been assumed to be constant. Our examples of chemical radicals were so selected that

perhaps be confusing to attempt to make such distinctions. The term superatom is used loosely, and is indiscriminately applied to charged as well as neutral systems. This usage coincides with that in vogue for the atom before the ionic conception was developed.

we could do this. If we had chosen to speak of the fatty acid series, in which we have a growth of complexity in the hydrocarbon or lyophobic radical while the carboxyl or lyophylic radical remains constant, we would have seen a gradually increasing insolubility, and our reconnaissance expedition would have been seriously impeded. Such polar systems will be discussed later. In the meantime, it seems urgent first to develop an interpretation of the problem of the solution which is definite enough to enable us to accept the presence of large amounts of water within the boundaries of our superatoms. This can perhaps be accomplished by the statement which follows. We shall regard water as a feebly polymerized system. Solid or liquid substances soluble in water undergo disintegration into particles of molecular or polymolecular dimensions. Under these conditions, all dissolved substances and their components enter into relations with the water molecules of the solvent by which the properties of both are appreciably modified. Water existing under such influence we shall regard as hydration water. This water is to a degree under the influence of the molecule, radical or ion to which it is attached and will be more or less involved in the history of the component with which it is associated. It follows then that all the radicals or atomic series that we have considered have, while in solution, associated with them more or less water, and that any adequate picture of such atomic series must take this fact into account, however much it may complicate the picture. The amount of water involved may be relatively negligible as in the case of sodium chloride, and will increase gradually, in a suitably arranged series, until we reach complex colloidal molecules like proteins, which have the power of associating enormous numbers of water molecules within their relatively vast labyrinthine boundaries. Moreover, the amount of water held in this way will be sensitively influenced by a great many and even apparently trivial factors. This is shown in a prophetic way by sodium chloride, which has so little affinity for water that it normally crystallizes without water of crystallization. If crystallized at low temperatures, it comes out of solution with two molecules of water of crystallization, which are, however, but feebly held.

It therefore now becomes necessary to enlarge our picture of the complex atoms that we have discussed in order to include the water with which they are associated. Moreover, in doing this we have simplified the transition from the complex atoms of the molecularly disperse systems to those of the colloidally disperse systems. We observe simple carbohydrate molecules in molecularly disperse solution, with much hydration water, undergoing polymerization, by which they become less and less disperse, until they reach colloidal dimensions, as in starch or glycogen, retaining throughout the transition an integral relation to a large, but probably gradually diminishing amount of hydrate water. Likewise, we see the amino acids, in which the hydrocarbon radical has been materially changed by the introduction of at least one highly water soluble group into the most strategic position in the molecule, being built up one unit at a time into structures having a molecular weight of 30,000 and upwards, in water, and in most cases having a high affinity for water.

Of these two cases, the former is most difficult to discuss from the atomic viewpoint. If the views just now being developed with respect to the starch molecule are correct, the latter is built up of atomic units known as amyloses and amylopectins. Perhaps the facts developed in the study of cellulose for the development of the viscose industry reveal the essential atomicity of this complex substance. These questions remain

for time and the experts in these fields to determine.

So far as the protein molecule is concerned, the situation is different. Here we have abundant information on the properties of the various components of the series. Each member possesses two interesting traits in common with all the other members of the series; it can act as an acid or as a base, depending upon circumstances. This property, other things being equal, depends upon the presence of free carboxyl and free amino groups. The protein molecule, therefore, becomes an enormous polyvalent amphoteric electrolyte having perhaps as many as thirty positive or negative charges on its molecule at times, depending upon the characteristics of the solution in which it lies. These charges may be increased or decreased to a maximum on both sides of the isoelectric point, and when charged the molecule shows cataphoresis. In all respects, these systems behave as huge polyvalent atoms would be expected to behave. Moreover, generally speaking, they are much more stable than the radioactive elements, although they are probably at least one hundred times heavier. Unlike the radioactive elements, these atoms of life are synthesized or broken down at will (given suitable materials and conditions) by special agencies existing in their natural environment. The syntheses involved are highly specific both as to product and agencies, and give rise to a special field of biochemistry, owing to the fact that only the living organisms can be used as the test-tube and retort for the study of certain characteristics of the proteins and allied compounds. The finest analytical work in chemistry is crude in comparison with the chemistry of the organism in dealing with the detection or identification of these compounds. In short, this highly hydrated poly-functional superatom is a remarkable organization which it is at present utterly impossible to describe adequately.

In the above, we have found it rather easy after all to build up a continuous atomic series ranging in size from the simplest hydrogen atom to protein molecules having molecular weights estimated at 30,000 or even more. In this series, we have representatives all the way from rapidly diffusible molecular dispersions to complex colloidal emulsions. Perhaps it would be the part of wisdom to terminate our "trail" here without attempting to hack away the underbrush necessary to make a true contact with general biology. However, wisdom is not a normal trait of an explorer in the face of such a challenge; let us press on.

Our problem now becomes that of passing from ultramicroscopic particles having unitary functions to larger ones visible to the eye and existing as morphological elements in cells. In common with other electrically charged colloidal particles, the protein molecules undergo precipitation by suitable reagents having charges with the opposite sign. Such reagents may be other protein solutions or other chemical reagents suitably chosen. Such changes often involve the production of visible aggregates, and in many instances the native protein can be recovered unchanged. But they are probably analogous to only a portion of the processes occurring in the living cell. For instance, all precipitations and engulfments of foreign masses by leucocytes, whether they be inanimate colloidal particles such as carbon or living cells such as bacteria, probably depend upon such colloidal chemical precipitation, perhaps frequently initiated by mutual neutralization of electrical charges or in other instances by a chemical attraction, which here becomes chemotaxis.

Moreover, it is quite possible that one factor in the deposition of proteins in the tissues in the first case is their dis-

charge by suitable changes in the hydrogen ion concentration; and in the second case, in so far as they become insoluble, this may be followed by polymerization involving secondary chemical changes. If the process stops in the first phase, such proteins would be mobilized by suitable changes by which they recover their charges, become more highly solvated, and are thereby drawn back into the zones of greater activity. Such events may occur, for instance, during starvation when much of the structural material is mobilized.

Regardless of the extent to which such precipitations occur and the size of the aggregates produced, it is clear that these particles are lacking in some part of the freedom or structural unity that they had before. They are, we may readily see, in some degree less lively than they were; so that, although it is more than probable that some of the visible structures in cells are built up in this way and perhaps play a skeletal or orientizing rôle, it is also more than probable that the essentially living portion is composed of structural units having more chemical and physical freedom, *i.e.*, tropisms. These are no doubt built up into definitely oriented structural patterns by which they achieve, and are endowed with, special physical and chemical functions in the cell. So far as the writer knows, no such complexes are actually known, nor are any criteria by which they would be recognized known. Of course, there has been much speculation by philosophers of all times, as well as biologists more recently, as to the physical-chemical unit of life, but no such unit has been isolated by experimental studies.

Instead of indulging in speculation, let us see if we can build up a background for such a complex upon which some of its characters might be predicated. In view of what we saw above, it is more than likely that any system having the properties required would possess more polarity than any of the systems that we have considered. Such polarity is best known in connection with the fatty acids. In oleic acid, for instance, the hydrocarbon group with its inability to unite with water so overwhelms the carboxyl group that it is of little avail except perhaps to orient those molecules that lie in the water-oil interface. However, in the sodium salt of oleic acid, the hydrocarbon radical is still strong enough to prevent molecular dispersion. If, however, we concede something to the hydrocarbon radical by replacing the hydrogen atom in water with the ethyl radical, we find that in ethyl alcohol our soap forms true molecular dispersions. A similar result is achieved in two ways in the organism. Fatty acids are rendered soluble in the intestine by the bile salts, which unite with them forming a colloidally or more probably even a molecularly dispersed system. So far as is known, this device is limited to the bowel. Tissue fats can, however, be modified by replacing one fatty acid radical with the phosphoric acid-choline complex and thus become capable of spontaneous peptization and of forming colloidal dispersions. In all such cases, the change is presumably due to the influences of the substituent on hydrate or solvate formation.

Now it is interesting to note the number and variety of hydrocarbon and other side chains in the protein molecule. It is easy to imagine that all these have certain more or less specific powers to hold other radicals in complex relations. The hydrocarbon radicals no doubt attach fatty or other hydrocarbon radicals, so that complexes between fat molecules and proteins are to be expected. The existence of such complexes has been conjectured, but so far as the writer knows, no such complex having indispensable relations to life has been described. However, we may dis-

cuss at least one interesting possibility of this sort. For instance, it is well known that the brain contains a surprisingly large amount of lecithin and allied substances. It is not difficult to visualize a union between the lecithin ion and the protein molecule, and this could occur through solvate union between the hydrocarbon radicals in both or through salt formation or through both processes. Such a union of two complex superatoms of contradictory polarity would give rise to a new complex having properties unlike those of either component. But in visualizing this union, we have failed to mention the large mass and variety of other molecules including water that will be carried into the complex and that will contribute to its properties and functions. With this system and its inevitable orientation, we can easily picture the conduction of a nerve impulse, for instance, as depending upon the continuity of the water phase, and the non-conduction under narcosis as due to an inversion of the emulsion with the consequent non-conductivity of the now continuous oil phase, as was suggested some years ago by J. S. Hughes.

In the foregoing discussion, we have seen rather clearly that the most readily seen morphological components of the cell are in a relatively passive state in comparison with the more lively and more transparent components. Intermediate between these extremes, we have the various cell organs, but especially the mitochondria, and in plants the various plastids involved in photosynthesis as well as the starch and oil formation. These visible organs carry on within themselves essential functions. Their continuation, once they appear, is almost certainly provided for by growth followed by division. If, now, we should suggest that these cell organs possess the essential traits of superatoms, it might be asked, but how can atoms grow and divide? Such objections can not of course be fully answered. We know that crystals grow and that the structure is specific. We also believe that they divide. However, closer analogies in the colloid field are easily obtained in which the phenomena under consideration can be imitated so that there may be no essential mystery in this part of the problem.

The problem becomes simpler again when we deal with bodies like free living cells of various sorts. Here we have superatoms large enough to be seen readily, which still obey the same fundamental law that we have been discussing. Although microscopically visible, they often show Brownian movement; in other cases, movement is due to cilia. They often behave like charged systems, and at other times show positive and negative chemotaxis. Although they are true living organisms, they nevertheless show definite relations so far as behavior is concerned to suborganismal systems. Perhaps this behavior has appeared rather surprising heretofore; now we must expect it in the atomic series that we are attempting to construct.

The above discussion constitutes a blazed-trail of superatoms—a continuous series extending from chemical atoms to superatoms which are sufficiently large to be visible as morphological units in the living organism. We have achieved our goal and might rest our case except for the fact that several interesting points have been brought out incidentally which, if gathered up and developed, may lead eventually to a generalized description of atoms and superatoms. Such a generalized description would be useful in isolating superatoms on any scale.

(1) All the atomic series developed possess a striking structural integrity coupled with an uncanny capacity to perfect and maintain this structure. We see it in acids such as sulphurous

acid and its tendency to perfect its structure as sulphuric acid by adding oxygen; we see it in acid salts in their tendency to pick up available base to complete their structure; we see it in the protein molecule of the living organism, in its unaccountable ability to maintain its structure. It is difficult to account for the fact that only a very small excess of essential amino acids, over and above the actual minimal requirements, is needed for maintenance of the nitrogen balance. It seems that the amino acids are taken up from the body fluids with great avidity. In this respect, the protein components of the organism are as efficient as a strong acid in "gobbling up" base to complete its salt structure. If we think of it in terms of chemical affinity, we are apparently dealing with a very powerful or a highly selective type of affinity.

(2) This peculiar tendency to complete and maintain a structural unity is probably the most outstanding perceptible characteristic of these systems. It is expressed as an organizing tendency. The complexity of a given superatom is determined by the complexity of its organization. Viewed in this way, the hydrogen atom has a life, or life history, which differs only gradually from the other members of a series and from organizations commonly accepted as living organisms. The difference is essentially a difference of degree and not of kind. Creation, at least within the range in which we are discussing it, was therefore a continual improvement in the utilization of simpler parts. In the elaboration of these structures, properties are continually increasing in variety and complexity. But this, too, is not peculiar to such systems. Tyndall long ago noted that the liquefaction of a gas entails the appearance of new properties, and this is still more true of its solidification. How rapidly properties change and new ones appear on mixing several substances in suitable ways is known to every one. Consequently, the gradual disappearance of a given property or the appearance of a totally new property in any such series is entirely to be expected on the basis of the known behavior of the simplest systems. We must still admit that life *per se* is a unique attribute because we can not create it *de novo* at will. However, it must also be admitted that the individual properties of living matter exist a few at a time in non-living matter, and that living matter may differ from the other only in the complexity of its inner organization.

For instance, we usually think of self-building, self-repairing and self-steering as unique properties of living matter, but many of these complexes have these properties to a striking degree, and all chemical atoms, as well, have them to a recognizable degree.

(3) The innate tendency to build superatoms does not depend upon any one kind of chemical or physical property. It seems clear that it always depends upon some kind of polarity, but if so, the nature of these polarities is probably still largely unknown. Although many of these systems have the essential qualities of an amphoteric electrolyte, it seems that their polarities are not limited to those involved in this concept. In brief, it is not possible in chemistry to predict all types of complexes that may exist, and it is likewise impossible to make similar predictions in this field of superatoms. It will at first be necessary to isolate the functional superatoms and to develop the knowledge in this field much as it was developed for the chemical atoms.

(4) The atom, in every case, when compared with neighboring states seems to represent a state of relative stability. Considered from this standpoint, it possesses essential characteristics of a phase, and it would be exceedingly interesting

to know just what J. Willard Gibbs thought about phases in such a general sense as would be involved here. The suggestion of the phase-like nature of the superatomic systems, and perhaps for that matter the atomic systems themselves, arises from the unexpected ease of synthesis of many of them. For instance, it might be expected that so complex a system as the hemin of hemoglobin would be next to impossible to synthesize, but Hans Fischer did not find it so. We might expect that the tetrapyrrole nucleus would be synthesized around the iron atom, but this was not the procedure used. The tetrapyrrole nucleus was first synthesized, the iron was then introduced and at the last this iron complex could be coupled with the globin component. Whether the organism approaches the synthesis in this way or not is not known, but it surely is not without philosophical significance that the same terminal products were obtained by the synthetic chemist as are obtained in nature. Perhaps it was the terminal quality of the products that made synthesis of so complex a product possible. We are quite familiar in chemistry with such terminal products. Often, from a thermodynamical standpoint, they represent maxima in entropy. At other times they arise from minima of solubility or electrolytic dissociation of an equilibrium component. Glucose in the form in which we know it represents such a terminal product. Under the influence of alkali or insulin, it develops new capacities to develop still more stable terminal products. Many other cases of this sort could be cited. Perhaps, in this quality, we have one of the outstanding characteristics of both chemical atoms and superatoms; they represent terminal products or resting stages in the evolution of matter. It is at once evident how useful such "breaks" in the continual flow of the energy of the universe would be for the safe operation of the physical-chemical machinery of life. They constitute landings or pauses in the stair-steps of evolution in which the requisite organization for the next step could be developed.

(5) The discussion in the preceding paragraphs viewed from a still greater distance manifests familiarity of another sort. We see that in the whole atomic-superatomic (or evolutionary) series there is a persistent reciprocal relation recurring at each level in the series between the atom in question and its environment. We see that in order that a given atom may be formed or exist, its environment must be fit. But this is the integrated relation between the survival of the fittest and the fitness of the environment pointed out by L. J. Henderson as holding for organic evolution. Consequently, the environment suitably conceived becomes an indispensable party to the development of a superatom of the next higher order. After it has come into existence, this environment supports and sustains the integrity of the superatom.

If we begin with the chemical atom, we find it existing in a given state in a given energy field. When we begin to organize these atoms into superatoms, we find that they too require a suitable energy field for their formation and existence. Each time we step up the complexity of the superatom we have to organize the environment to a higher level also in order to realize the new step.

This principle is the most sweeping generalization developed in this paper, and if true provides for continuous series of atoms and superatoms all the way from the electrons or the simplest chemical atom to the solar system and perhaps even larger organizations of astronomical bodies and formulates at least one generalization common to them all.

In conclusion, it should be said that

one thing stands out clearly in the mind of the writer. He is fully aware that he has seen some things "through a glass darkly" that others are able to see "face to face." This is always true in any such pioneering synthesis as this paper represents, and it is to be hoped that the reader who has read so far has been as much diverted by his own superior knowledge of some of the matters under discussion as by anything that he has read. Unless the writer is mistaken, the main part of this essay deals with matters that are obvious, *i.e.*, are intuitively known to many. The writer, however, believes that they ought to be said because in the saying they become tangible landmarks of future progress.

Biologists of every sort, including the applied biologists of medicine, are frankly hopeful for the elucidation of their most perplexing problems through developments in the field of chemistry. It now appears that they can help materially by working with us, with their superior experience in morphological concepts, and by helping us to select and purify the atomic-superatomic systems in this field of neglected dimensions. There seems to be no doubt, if we can break this virgin field to the plow, that an abundant crop will be obtained.

THE RAMAN EFFECT

By Dr. GEORGE GLOCKLER

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In March, 1928, Professor C. V. Raman, of the University of Calcutta, announced the discovery of a new type of scattering of light observed in various liquids and gases. The study of this mode of light scattering by molecules bids fair to become one of the most powerful tools of the chemist and physicist for the investigation of molecular structure. The type of information concerning the internal structure of molecules revealed by these experiments could heretofore be gotten only by studying the absorption (or emission) of light in the infra-red region of the spectrum. This discovery by Professor Raman makes it possible to carry out the same study in the visible region of the spectrum. This is a tremendous advantage because the spectroscopic technique is very much easier and is much further developed in the visible region than in the infra-red. Professor Raman has studied the phenomenon of light scattering for many years, and his recent discovery is no doubt epoch making and compares in scientific importance to the discovery of X-ray scattering by A. H. Compton, of the University of Chicago, for which Professor Compton received the Nobel prize.

The object of this article is to present the subject of light scattering and to show the relation of the Raman effect to other phenomena which have to do with the interaction of light and matter.

Fluorescence

The phenomena of the scattering of radiation by matter has been studied by physicists and chemists for a long time. Every one is acquainted with the facts that certain dyes show fluorescence under the proper conditions. If a little of the dyestuff "fluorescein" is dissolved in water made alkaline and the color of the solution is noted by holding the test-tube up to the window it is seen that the solution has a yellow color. If the observer now turns around he will note a greenish shade. In the first instance, the solution was observed by transmitted sunlight and in the second case the effect of scattered sunlight was observed.

The explanation of this phenomenon is as follows. The molecules of the dyestuff have the property of absorbing certain colors from the sunlight, which is composed of all the colors of the spectrum. Those colors that are not absorbed by the dyestuff are of course transmitted by the solution and they were observed in the first experiment described above. In the second experiment the colors that were scattered by the molecules of the fluorescein were observed. This explanation is given in the most general terms and the case must now be restated in terms of the theory of the constitution of light and matter as held at present by physicists and chemists.

The Nature of Light

It is quite impossible to describe here in detail all the phenomena regarding light which have finally led to the modern concepts of the theory of radiation. However, it is well known that there exist two rival concepts of the nature of light. On the one hand, the electromagnetic theory of the nineteenth century considered light to be an electrical phenomenon in the nature of a transverse vibration in the light-carrying medium, the ether. Such phenomena as inter-

ference of light waves, their diffraction on small objects (small holes, needles, edges, etc.) could very completely be described on the view that light is some kind of disturbance propagated as waves in a medium. However, other observations by physicists, such as the photoelectric effect, the Compton effect and the Raman effect, were difficult to understand on the basis of a theory that proposed light as a wave phenomenon. To explain these effects a new theory of radiation was invented. It is called the quantum theory of light because it proposes to consider a beam of light leaving its source as a stream of small entities called quanta. It is seen that the quantum theory of light is quite analogous to the corpuscular theory held by Sir Isaac Newton. However, it is believed now that these modern light quanta have quite a different set of properties from Newton's corpuscles. This is of course because a little more is known about the behavior of light and its interaction with matter than Sir Isaac knew. Of course light of the seventeenth century is probably the same as the radiation observed now, only our knowledge has changed and therefore our point of view and so our theories. In order to explain the observation of the physical world about us, human reasoning endows light quanta with just the properties they ought to have so that they could produce the effects as actually observed. And so there is associated with each light quantum a certain amount of energy and also momentum and a certain velocity, just as similar concepts are associated with a bullet or a cannon-ball. Should any one observe to-morrow some new phenomenon regarding light which would be quite inexplicable on the present ideas regarding radiation, it would be necessary to improve or change our concepts until such a view had been adopted as to the nature of light as would allow us to "explain" the new phenomenon.

If one now thinks about a certain beam of monochromatic light, say red light, there exists then the possibility of considering it as a vibration in the ether of a certain frequency, or one may think of it as made up of quanta of red light of a certain energy traveling through space with a certain velocity. Clearly the light is the same and the difference is simply due to the two different ways of calling it names. Evidently there must be a connection between the two modes of thought concerning the same thing, and Einstein has given such a relation between the energy E and the frequency ν of a light quantum:

$$E = h\nu$$

h = Planck's constant and it may be thought of as a proportionality constant. It is seen then that a quantum of red light (which has a smaller frequency) has less energy than has a quantum of blue light, which has a higher frequency. And since the frequency ν of a vibration and the associated wave-length λ are related to the velocity c of the undulation by

$$\nu\lambda = C$$

it is seen that a longer wave-length is connected with less energy. If for instance a blue light quantum be converted by any process whatsoever into a red light quantum then some energy had to be given to some other body because the resultant red quantum has less energy than had the initial blue quantum. This reasoning involves the principle of the conservation of energy. The relation just established between the energies and the frequencies (or colors) of light quanta is all important in our future considerations.

Absorption and Emission of Light

The process of absorption and emission of light can now be described very simply. The first fact of experiment to note is the observation that all materials

show specific absorption and emission of light. This means that a given kind of matter will only absorb or emit certain colored lights. The theory which explains these observations has been developed by N. Bohr on the basis of the electrical constitution of matter. A hydrogen atom which consists of a positively charged nucleus and an electron can absorb a series of light quanta of very definite frequencies and no others. The process can be expressed very concisely by means of equations such as the chemist uses for writing his chemical reactions:

$$H_0 + h\,\nu_{01} \rightleftarrows H_1$$
$$H_0 + h\,\nu_{02} \rightleftarrows H_2$$

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The process of combination of the normal hydrogen atom, H_0 and $h\,\nu_{01}$ is of course the process of absorption and leads to the formation of an excited hydrogen atom H_1, H_2, etc., depending on the kind of quantum absorbed. It is seen that the reverse reaction (the equation read from right to left) is the decomposition of an excited hydrogen atom and this process constitutes the emission of a quantum and therefore the production of light. The various excited states of hydrogen are called higher energy states of hydrogen because the atom has more internal energy, and it is supposed that the electron resides in various energy levels depending on the amount of excitation. The situation is pictured graphically in Fig. 1.

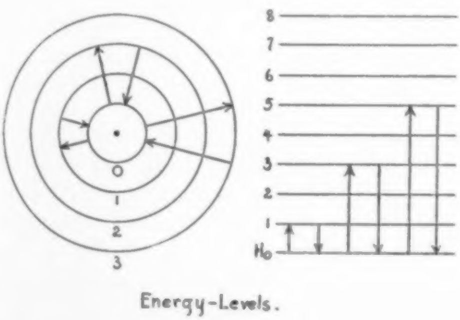

FIG. 1

The various energy levels of an atom are related in magnitude by a simple system of whole numbers called the quantum numbers. Atoms can exist in the various electronically excited states just described, and they have no other possibility of absorbing energy within their structure, whereas molecules may absorb energy in three different ways. They may be electronically excited as the atoms or they may take up internal energy in the form of increased vibration of their component parts. It is found that the vibrational states of a molecule are also related to one another in the order of small numbers. The third way by which molecules can take up external energy increases the rotational energy of the molecular system. The notion that a molecule can take up energy in the three ways just stated is of course purely a guess.

No one has seen an electron "displaced" to a "higher orbit" or a molecule "vibrating" or "rotating" in a "higher quantum state." However, such a guess or theory can be compared with experimental facts known about light (*i.e.*, energy) absorption of molecules, and if the deductions of such a theory compare favorably with the experimental findings, then it is said that there exists a satisfactory theory.

The dual nature of light as a wave and quantum phenomenon and the arbitrary nature of quantum numbers are now explained in a more satisfactory manner by the newer theory of atomic structure called wave mechanics. It is not only assumed that light has a dual nature but that particles (electrons, for instance) have also some of the properties ascribed to waves. All the problems which have to do with the scattering of light by matter can be stated in terms of these newer theories. However, it appears that the quantum view is sufficiently clear to

present an insight into the effects to be discussed here, although certain aspects of these phenomena can best be understood on the basis of wave mechanics.

The Tyndall Effect

The simplest kind of scattering process is the interaction between a particle or molecule and light quanta whereby neither of them is changed in nature or energy content. However, the direction of the scattered quantum may differ from that of the incident light. This simple case of scattering is observed every time a sunbeam plays with the dust particles in a darkened room and makes them visible. The effect is known as Tyndall scattering. The scattering process (in the case of molecules not at absolute zero) may be portrayed in a simple way by means of the equation:

$$M_0 + h\,\nu \rightarrow M_0 + h\,\nu_\theta$$

where $h\,\nu_\theta$ is an incident quantum; M_0 is the particle or molecule in the normal state, and $h\,\nu_\theta$ is the quantum scattered in a direction making the angle θ with the incident beam. Usually one observes such scattering effects at right angles to the incident beam. It is to be noted that the frequency or color of the incident and the scattered quantum are the same.

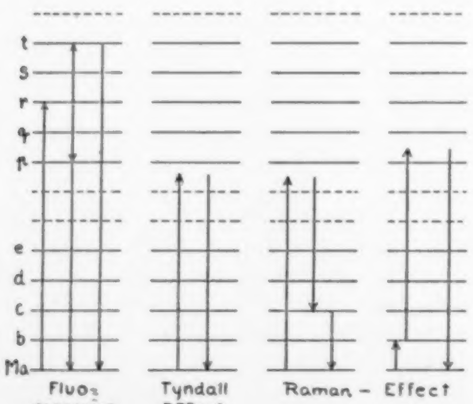

Fig. 2

The Case of Fluorescence

The simple experiment cited in the introduction can now be explained as follows. When a molecule of fluorescein shows the phenomenon of fluorescence it undergoes the following changes.

First, the incident light is absorbed by the molecule and it is thereby excited or placed into a higher energy level. It may well be that in the general case some electron is lifted into a higher quantum state and at the same time certain portions of the molecule vibrate relative to one another, and the molecule rotates, with more energy than in the normal state.

$$M_a + h\,\nu_{ar} \rightarrow M_r$$

is a shorthand statement of the absorption act, or we may refer to Fig. 2 and consider the molecule now in a higher energy level (M_r).

Second, if the molecule would now return to the normal state with the emission of the same quantum of light (the same color or frequency) then the act of emission of light, in this case, resonance, would have taken place. This case has already been discussed above. It is, however, conceivable that the excited molecule of fluorescein may make an impact with the solvent molecules or another fluorescein while it is still in the excited state. If it is now supposed that the excited molecule loses, during the impact, a part of its excitation energy to the other molecule (as kinetic energy, for instance) then it would be brought to a lower energy level (Fig. 2.).

$$M_r \rightarrow M_p + \text{Kin. Energy}$$

Third; it is seen that the excited molecule has now a smaller energy content and if it should now return to the normal state by emitting the quantum ($h\,\nu_{ap}$) corresponding to the state M_p then the emitted light is a quantum of smaller energy and the scattered light would necessarily be of a color towards

the red end of the spectrum when compared with the incident quantum:

$$M_p \rightarrow M_a + h\,\nu_{ap}$$

It is a fact that the fluorescent light is in most cases of a color on the red side of the exciting or absorbed light, and so the picture drawn above does explain this fact of observation.

But not all fluorescent light is located on the red side of the exciting light! Some cases are known where the color of the scattered quantum is on the violet side of the absorbed light. How can this situation be understood? It is only necessary to assume that a molecule in the excited state can not only lose but also gain energy during an impact with another molecule. It is then seen that the emitted quantum can have more energy than the absorbed one:

$$M_r + K.\,E. \rightarrow M_t$$

which act is followed by

$$M_t \rightarrow M_a + h\,\nu_{at}$$

Or it may be supposed that a few molecules have been brought to a higher excited state by temperature distribution. If these absorb the incoming light they may be brought to the excited state M_t. As before "an anti-Stokes line" would result in emission.

The fluorescent light ($h\,\nu_{at}$) which has a color towards the violet end of the spectrum when compared with the incident or absorbed light is known by the name of anti-Stokes light because Stokes, an English physicist, first put forward these considerations. It is seen that this reasoning applies the law of conservation of energy to the process under discussion.

Another conceivable mechanism is the following. It may be supposed that the excited molecule has a great probability of emitting a quantum of small energy (an infra-red quantum perhaps).

This act of light emission would bring the molecule to a lower quantum state. A second act of emission would bring the molecule to the normal state:

Absorption: $M_a + h\,\nu_{ar} \rightarrow M_r$
Partial emission: $M_r \rightarrow M_p + h\,\nu_{pr}$
Fluorescence: $M_p \rightarrow M_a + h\,\nu_{ap}$

To explain the formation of anti-Stokes lines it would have to be supposed that the excited molecule (M_r) can absorb from the surrounding temperature bath some small quantum ($h\,\nu_{rt}$) and the mechanism would be:

Absorption: $M_a + h\,\nu_{ar} \rightarrow M_r$
Additional absorption: $M_r + h\,\nu_{rt} \rightarrow M_t$
Fluorescence: $M_t \rightarrow M_a + h\,\nu_{at}$

In an actual case it is probable that a complicated molecule has many possible energy levels and the fluorescent spectrum may be one of great complexity.

It must now be noted that in the Tyndall effect all wave-lengths of light are scattered though not to an equal extent, and a beam of sunlight has a bluer color after scattering. However, in the case of fluorescence it is seen that the molecules absorb only certain frequencies of the incident light and emit light of definite frequency depending upon their energy levels, that is, upon their constitution.

The Raman Effect

If a beam of light is of such a color that it does not correspond to one of the energy levels of the molecule by which it is scattered, it would be expected that only Tyndall scattering would occur. However, Smekal in 1923 proposed the idea that after all there may exist the possibility that the molecule may interact with the incoming quantum to a sufficient extent to abstract from the beam some energy and be thereby brought into a higher quantum state. It may well be that the probability of the occurrence of such an act is very small as compared with the probability of simple scattering (Tyndall effect). This phenomenon has actually been observed by Professor Raman and constitutes the scattering process now known as the Raman effect. The Raman effect may then be considered as a Tyndall effect with complications. The complication is the reduction

of the energy of the quantum caused by the fact that the molecule is raised to a higher energy state. This interaction can take place between light of any color and absorption in the ordinary sense need not take place. The phenomenon may be described by the equation:

$$M_a + h\nu_o \rightarrow h\nu_1 + M_c$$

where now

$$h\nu_o - h\nu_1 = E_c - E_a = h\nu_{ac}$$

where E_c and E_a are the energies of the molecule in some excited and the normal state respectively and ν_{ac} is the frequency of light which would bring the molecule into the excited state M_c from the normal state M_a by absorption.

The scattered light would have a frequency ν_1 displaced towards the red of the spectrum when compared with the incident quantum ν_0. The displaced lines observed on a photographic plate are called the Raman lines. The difference $(\nu_1 - \nu_0)$ between these and the lines ν_0 produced by Tyndall scattering must be connected with the energy level system of the scattering molecule. In this way it is seen that the study of the Raman effect can give valuable information concerning the constitution (energy levels) of molecules!

It is natural to consider next the possibility of the interaction of a quantum ν_o with a molecule which is already in an excited state due most likely to temperature distribution. In this case it may happen that the molecule may give to the incoming quantum its excitation energy and return to a lower energy state, perhaps the normal state. This case is quite analogous to the situation discussed under fluorescence. This action can be described conveniently by the equations:

$$M_a + \text{Kin. Energy} \rightarrow M_b$$
$$M_b + h\nu_o \rightarrow M_a + h\nu_2$$

and

$$h\nu_2 - h\nu_o = E_b - E_a = h\nu_{ab}$$

The corresponding Raman line would be formed on a spectrum plate on the violet side of the Tyndall line. It would be an anti-Stokes line, and such lines are actually found in the Raman spectra of many substances.

The difference between fluorescence and Raman effect is then the following. In fluorescence the incoming quantum is absorbed and corresponds to one of the energy levels of the molecule. Similarly the fluorescent light is related to the energy states of the molecule. In the Raman effect the incoming light is not an absorption frequency of the scattering system, nor is the scattered quantum related to the energy diagram of the molecule. However, the difference between them is related to the energy levels of the scattering molecule, and in certain cases it is true that this difference corresponds to an absorption frequency in the infra-red. In general a Raman line will occur between levels that combine with a third level.

This deduction is a result of wave mechanics. The Raman spectra studied so far have been correlated to the vibrational and rotational changes in the molecules and for this reason are of great importance to chemistry.

The Raman Effect and Molecular Structure

The group of substances known as hydrocarbons consist of carbon and hydrogen only and they contain the $\equiv C-H$ grouping. The vibrations of these two atoms relative to one another can be changed by absorption of light in the infra-red. Similarly a hydrocarbon molecule will emit infra-red radiation if it should change from a higher to a lower vibrational state. This type of spectrum can be observed in the Raman effect and the experiments are usually carried out by the use of the various visible lines of the mercury arc, the scattered Raman radiation being observed

at right angles to the incident light. In this manner the chemist can obtain a knowledge of the forces and binding energies holding the various atoms and groups of atoms together, and he can make his observations in the visible spectrum rather than in the infra-red, where experimentation is most difficult. Many groupings of atoms such as C – C, C – H, C = O, C ≡ N, NO_2, CH_2, CCl, HCl, NH, NO_3, CO_3, etc., have already been studied, and it is clear that many investigations of this type will be carried out in the near future which will result in a great increase of knowledge regarding molecular constitution. Since the discovery of the effect in 1928 already over two hundred scientific papers have been published on the subject.[1]

There are many features regarding the Raman effect which are of the greatest interest especially to physicists which have not been dealt with in this discussion for the reason that they would complicate the presentation and destroy the clearness which it is hoped has been attained.

It is thought that the method of representing the various processes involving quanta and molecules by means of equations is very useful. One more scattering process to be represented in a simple way by such an equation is the Compton effect, which has a great analogy to the Raman effect. It will be remembered that in this case a quantum of high frequency (X-rays) interacts with an electron of a scattering material. The quantum is thereby changed in frequency and momentum, the electron is dislodged from the scattering substance and gains energy and momentum:

$$E_0 + h\,\nu_0 \longrightarrow E_{fast} + h\,\nu_1$$

where E_0 is the low energy electron as residing in the scatterer; E_{fast} is the dislodged fast electron, $h\,\nu_0$ and $h\,\nu_1$ are the initial and scattered X-ray quanta.

One more point of interest in this connection is the fact that the use of these equations leads to a clear understanding of the relation of some of the processes involved. If the Raman effect resulting in a quantum of lower frequency is considered it is seen that the reverse of this reaction leads at once to the prediction that anti-Stokes lines should also be possible, for it is a result of thermodynamics that for each elementary process there should exist a corresponding reverse process. This principle has been called variously the principle of entire equilibrium, of detailed balancing or of microscopic reversibility.

[1] Comprehensive scientific articles are: (1) A. S. Genesan and S. Venkateswaran, "A Memoir on the Raman Effect," *Ind. Jl. Phys.*, 4: 195, 1929; (2) "Molecular Spectra and Molecular Structure," *Trans. Faraday Soc.*, September, 1929; (3) A. Dadieu and K. W. F. Kohlrausch, "The Raman Effect in Chemistry," *Berichte*, 63: 251, 1930; (4) C. Schaefer and F. Matossi, "The Raman Effect," *Fortschritte der Chemie*, etc., 20, No. 6, 1930.

AN INDIAN SOCIAL EXPERIMENT AND SOME OF ITS LESSONS

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When social engineers come into their own as custodians of the collective welfare, cultural anthropologists believe that they will find descriptions and analyses of experiments in collectivism by the less civilized peoples of very considerable benefit. Or rather, they will probably have studied them in preparing for the degree in social management. It is true that the conditions under which such experiments were made were quite different from our own but the minds that had to grapple with them were essentially the same. To the study of one primitive social and governmental experiment of this sort, that undertaken or evolved by the Creek Indians who formerly occupied most of the territory of the present states of Georgia and Alabama, I invite your attention.

North of Mexico the confederate organization of the Creek Indians was surpassed in ingenuity and completeness only by that of the Iroquois, though the names of none of the geniuses who contributed to its construction, the counterparts of the Iroquois legislators Dekanawida and Hiawatha, have come down to us. This probably means that it was a complex, slower in growth and more natural than the one so successfully launched by the northern Indians.

The higher tribal organizations found in America rested on a type of farming which has been called milpa agriculture. The principal exceptions seem to have been on the Western plains where peoples were held together by the communal bison hunt, and on the north Pacific coast where immense natural food supplies were to be found on a narrow strip of territory and where a property-competition pattern brought people together annually in towns of considerable size. But even here governments were practically confined to single towns.

The main crops of the Creek Indians, as of the other agricultural tribes of North America above Mexico, were corn, beans and pumpkins, though small amounts of tobacco were also grown and occasionally sunflowers. Corn was their staple among vegetable foods, occupying much the position of wheat in the Old World. It was raised both by individuals—usually old women, in small scattered plots—and in large communal fields, one of which was planted and cultivated by the men and women of each town working together. This last was divided into sections for the separate families by narrow strips of grass, but all labor except some of the harvesting was in common. A certain portion of every crop went into a town granary in charge of the chief for use on occasions of common concern, such as ceremonies, the entertainment of emissaries from other tribes and the relief of families reduced to want by unforeseen misfortunes. It is probable that this system of cultivation was introduced into the Gulf region along with corn itself, and it is interesting to speculate whether the more closely knit social organizations which we find in the corn area were due more to the corn or to the communal method of caring for it.

The weakness of Creek economics—and this was true of all other agricultural tribes north of Mexico—lay in the related facts that they had no domestic animals except the dog and made practically no use of fertilizer. It is rather

singular that the only references to fertilizer come from certain loosely organized fishing peoples of the north Atlantic coast who are said to have put fish and seaweed in their corn-hills, but there is no evidence of its use by any of the Gulf tribes before European contact. This of course meant periodical exhaustion of the fields except in a few favored sections, an exhaustion all the more frequent because of the shallow cultivation which the rude native implements rendered necessary. This and the depletion of supplies of firewood made removal of the entire town from time to time a convenience if not a necessity. We know of some towns which existed in approximately the same situations for two or three hundred years, but this means that the same general position was maintained and in point of fact there was often considerable shifting within a given area.

In any case periodic desertion of the town was universal during the hunting season. The dog was rarely eaten, never used as a draft-animal and probably not employed in hunting. Although bison formerly existed in considerable numbers in the territory of our present Gulf states, the deer seems always to have been the main source of flesh food, and deer hunting involved the abandonment of the regular towns twice annually. Moreover, although deer drives were occasionally resorted to, most hunting was undertaken by single families or small groups of families, and this fact tended to break up the solidarity of the tribe. Bear were usually hunted by small groups also, but we encounter a community device in the shape of a "bear park," a tabued territory reserved for the town as a whole and visited at fixed periods.

Fish were taken by individuals or by groups. Collective fishing was confined to the dry season when some streams had shrunk to detached pools which could be poisoned or dragged, and was participated in by an entire town or neighborhood.

As so often happens, the ceremonials furnish an excellent index of the tribal economic foundations, and the most important of all was the great "busk" or "green corn dance," as it is popularly called by whites, celebrated in July or August when the first flour corn was ready to eat. In the more ancient ceremonies four ears of corn were brought into the ceremonial ground and laid beside the four main sticks of the sacred fire. This was always done, but occasionally a piece of meat or four fish were added, showing the importance, but at the same time the secondary importance, of flesh food.

Here, then, we have certain factors—agriculture and communal fields, expressing themselves in common ceremonials, group fishing, bear parks, occasional bear drives—tending to encourage a stable town life, an increase in population and community feeling; and certain others—no domestic animals of economic importance, no use of fertilizer, periodic separation to obtain meat—exerting an influence in the opposite direction. We should expect in consequence a social organism more closely knit than would be the case with a purely hunting or food-gathering people but one not as firmly bound together as in regions where there were no such disabilities. In fact, we do find our expectations realized in a general way, but we also discover that it is impossible to predict a set social expression from a given economic condition. Without going outside of the Southeast, we find quite diverse social and governmental systems erected upon an economic base practically identical with that which has been described. The Natchez constituted a theocratic absolutism, or rather oligarchy, the oligarchy being exogamous and perpetuated in the female line. The Chitimacha of Louisiana and the Timucua of Florida were

also governed by oligarchic groups, but these were endogamous, *i.e.*, true castes. The Choctaw, though raising much more corn than the Creeks, had a weaker central government, less inequality between chiefs and people, and a poorly developed social and ceremonial system. The Chicasaw were intermediate in many ways between Creeks and Choctaw but were more closely knit internally and more perfectly organized for war. The Cherokee were a loose confederation of related towns which seem to have had a kind of ceremonial capital but no civil capital, leadership being vested in the heads of the seven social groups or clans of which it was composed. The Yuchi were the only tribe in the entire region which had what we might call "societies," and upon the two into which they were divided rested leadership in civil and military affairs, respectively. Some of the Siouan tribes of the Piedmont section were little dictatorships, and among them a primitive form of trade and manufacture had begun to affect the economic and social structure. A little farther east, in the tidewater sections of Virginia and North Carolina, trade and the manufacture of a kind of shell money seem to have paved the way for sporadic "empires" like those of Wingina and Powhatan, which were in part probably a reflection of the pressure exerted by inland peoples. In spots along the Atlantic and Gulf coasts and in favored places between the larger tribes were lodged small bodies of Indians, often made up of refugees or outlaws, which were of a democratic complexion, as might have been anticipated. Among the Atakapa of southwestern Louisiana and Texas this type of organization was normal and in this instance may well be coupled with the fact that they raised little or no corn. In an interesting note one of our early informants tells us that there were to be found near the Choctaw gipsy-like bands who followed the herds of bison from place to place and lived in a very rude manner.

This brings us to a consideration of another set of factors—genetic relations and associations based upon them. These are operant perforce among all people, but are more conspicuous in primitive societies than in our own. Hewitt considers them to have been more powerful than any others in cementing the League of the Iroquois, but they were almost equally in evidence in the Creek Confederation, and were at work in the evolution of every little Indian commonwealth.

Through relationship, real or imagined, a Creek was bound first to his own clan, next to several other clans, next to the tribe and finally to other tribes. The Creek clan was a body of supposedly related people usually bearing the name of some animal. Not long ago a considerable school of students of primitive society held that group or clan relationships were chronologically prior to family relationships, but nearly all American ethnologists believe rather that the family idea has been extended to the clan. However that may be, the fact remains that a Creek stretched the terms for mother, maternal uncle, brother, sister, nephew and niece over most of the clan to which he belonged, and the terms for father, paternal aunt, son and daughter, as also brother and sister, over most of his father's clan. There was absolute prohibition of marriage in the mother's clan and blood relatives in the father's clan, and a distinct opposition to marriage in the father's clan in its entirety; but the sense of relationship went still further, for there was a special designation for the clan of the father's father. Moreover, the clan of each parent was often one of a group to which the same exogamous laws applied so that, for instance, a man who belonged to the Alligator clan could marry neither a woman of the Alligator clan nor one of the Turkey clan. Some of these linkages, like the one mentioned, held throughout the entire Creek nation, but in many of

the fifty towns of which it anciently consisted there were special groupings of clans proper to that town or to a small number of them. These were brought about by the institution of clan councils, associations of clans under the leadership of the oldest or most influential male belonging to it, its "uncle" in an eminent sense. They usually included members of clans considered to be related throughout the nation, but if there were a few members of a certain clan in one town having no natural affiliations they would unite with some one of the existing councils, and usually the children of this clan would consider the other children connected with the council as brothers and sisters with whom they would on no account marry.

The above description applies to the later years of the confederation. At an earlier period, if we are to believe many native informants, there was still another complication. All the clans of each town are ranged into two sections or "moieties" called Hathagalgi or "Whites," and Tcilokogalgi, "People of a different speech," which we will call Hathagas and Tcilokis for short, substituting the English plural for the Creek. These are well-known divisions which determine the alignment of the men in practice matches of the great Southeastern ball game, a form of lacrosse, the Hathagas opposing the Tcilokis. There is, however, a very strong tradition that these two moieties were once exogamous as such, that is, that a man belonging to any Hathaga clan could marry neither a woman of his own clan nor one of any other Hathaga clan, and similarly that a Tciloki could not marry a Tciloki. Again, the moieties were not made up of the same clans in every town so that further complications arose when a man or woman wanted to marry outside of his or her own village. Since marriage into the father's clan or the father's clan group was also frowned upon, and there were limitations of age and certain others to be mentioned presently, it is evident that the number of potential wives or husbands from whom a Creek might choose was relatively limited.

As the leading clans or groups of linked clans and the two moieties were represented throughout the Creek nation, a man belonging to one town should normally find some group in every other town which would recognize him as a brother, there would be others affiliated with the clan of his father and still others into which he might marry. If his clan or its equivalent was wanting in a town which he happened to visit, he was almost certain to find one corresponding to that of his father or grandfather, and his own position would be oriented by reference to these. For instance, the Bear clan might be represented in two towns, one of which might also have a Deer clan but no Raccoon and the other a Raccoon clan but no Deer. A man of the Bear clan moving from the first to the second would find his own people and he would take up, along with them, the attitudes they had established toward the Raccoon clan, although that clan was wanting in his own native settlement. If he belonged to the Deer clan, however, he would naturally transfer to his new associations the attitudes toward the Bear clan which he had already established, and the attitudes of the Bear people in his adopted town toward the Raccoon would tend to determine his own attitudes toward them. It is easy to see how important a knowledge of genealogy was for officers of the Creek towns entrusted with the perpetuation of the collective institutions, and we know in fact that prospective marriages were often the occasion for long and serious deliberations.

We must now consider intertribal manifestations of this relationship system. The numbers of a tribe might be increased by voluntary settlers, but the greater part of those who came in as

individuals were captives. Under the conditions of Indian warfare the most merciful tribe was apt to survive because it made up its losses more rapidly than a tribe which systematically killed all prisoners, and the larger and more successful tribes were most noted in this respect. Hewitt tells of one occasion on which the Iroquois instructed a small people that had come to live with them as to the importance of preserving captives alive. Upon the whole, however, it does not seem probable that the Iroquois and Creek confederations excelled because of the number of individual captives which they incorporated but because of the fact that they had established a technique for the admission of entire bands and small tribal remnants. The nature of this and its assumed origin is given in a Creek story of which the following is an abstract.

The Coweta and Kasihta, the two most important Eastern bands of the original Creek stock, moved into their territories from the West, accompanied it is claimed by one or two others. If there were others, however, they were left behind by these two which continued their conquering career as far as the Atlantic Ocean. At last there were no opponents left, and, wearied of inaction, they held a council to determine what was to be done. After long deliberation it was decided that, as a "moral equivalent for war," the two peoples should meet periodically in encounters on the ball field. After this any town or tribe which established friendly relations with Coweta could become a part of the confederation and would play on the Coweta side, and a town establishing friendly relations with Kasihta was similarly allocated on the Kasihta side.

In course of time not only were a number of towns of the same speech gathered into the federal body in this manner, but people more distantly related, such as the Hitchiti, Alabama and Koasati, and finally peoples very remotely related or related not at all—the Natchez, Yuchi and one or two bands of Shawnee. In this last case, a position in the confederation was actually made for a foreign tribe since the greater part of the Shawnee were never connected with it and those who actually joined subsequently returned to the rest of their people.

The relations between the Creeks and another independent body, the Chickasaw, are equally instructive. Early in the eighteenth century a small band of Chickasaw settled near the British post at Augusta, Georgia, but later moved over into the Lower Creek country and established themselves near the town of the Kasihta. Later they returned to their own people, but the alliance which they had meantime formed persisted and applied to the entire Chickasaw nation, so that, in 1793, when war broke out between the Creeks and Chickasaw, the Kasihta refused to take up arms with the other Creeks and their right to act in this independent manner was never questioned. At a somewhat earlier period, when the French and Choctaw were pressing hard upon the Chickasaw, the latter debated removing *en masse* into the Creek country, and if they had done so they would undoubtedly have taken their place as a town of the same "fire" as Kasihta. Orators of some Creek towns went so far as to claim the white colonists of South Carolina for their division.

It is important to take note of the several sorts of attitudes established by the above associations. Kinship served as a point of departure of one series which extended, as has been described, not only to every one in the same town but potentially also to the inhabitants of other towns of the same tribe and finally to foreign tribes. A member of the Raccoon clan, on visiting the Chickasaw, would discover a Raccoon clan there and representatives of that clan would accept him as a brother and entertain

him as long as he chose to remain among them. A Creek who belonged to the Deer clan would find friends and relatives of this type not only among the Chickasaw but also among the Cherokee of the southern Appalachians and the Timucua of Florida. Had he strayed so far and had there been no war between the tribes, a man of the Bear or Wolf clan would undoubtedly have been entertained similarly by the Bear or Wolf people of the Mohawk of New York, the Chippewa of the Great Lakes or even the Tlingit of Alaska. And, although I know of no specific cases, I think it evident that members of clans not directly represented in many of these tribes would have discovered indirect connections through which they would have found some means of allocation in the foreign group.

This does not mean that clan connection completely effaced national, racial or linguistic differences, any more than does our modern freemasonry, which in some ways it resembled. Even within the Creek nation itself the influence of clan connection was seriously modified by the dual town system already descibed. In fact, social communion and marriage were distinctly encouraged within the same town divisions, while contact with or marriage among those of the opposing town group was as distinctly discouraged. In other words, side by side with clan and clan-group exogamy we have town endogamy. The latter distinctly modified the former.

Again, there was a definite though varying attitude between towns of diverse language and culture although belonging to the same division. There was less likelihood that a man of the dominant tribe, the Muskogee, would marry a woman belonging to an incorporated tribe than that he would marry one of his own though of a different town, and he was less likely to marry a Yuchi or Shawnee than some one from the cognate Hitchiti or Alabama. The feeling was not, however, one of superiority but of diversity in character and feeling. A Muskogee would poke fun at the, to him, queer customs of a Hitchiti, an Alabama, or a Yuchi, and laugh at his speech, but he did not hesitate to place a Hitchiti of merit over the entire nation, he followed an Alabama to war and he had a wholesome respect for the Yuchi. And of course aversion to tribes which were entirely dependent was much more intense. Since, when two tribes went to war, intermarried members of both were apt to be the first sufferers, there was so much less incentive to foreign matches.

There were thus two Creek institutions which tended to preserve peace with other tribes and increase the federal body. One of these, the clan system, was shared with various peoples of America and indeed of the world. It was able to function well only in areas occupied by tribes having a similar clan system, but where the naming of clans was of another character it could operate only with difficulty. Thus, kinship would help a man of the Bird clan among the Cherokee, Timucua and Chickasaw, but not among the Choctaw, who had practically no clans named from animals. The institution of town moieties and a tribal adoption system, on the other hand, was, if we except the Iroquois and some peoples related to them, specifically Creek. It was this which built up their confederacy into a formidable defensive and offensive organization and gave it its conspicuous place in our early history.

Having examined the Creek state on its conservative side, we must now look at the factors which tended to keep it separate from other peoples and inculcate an unfriendly attitude toward them. In the first place, one of the two clan moieties of which mention has been made, the Teiloki, was concerned with war, the Whites, as might have been anticipated, having a similar association with peace. With the former was also

linked one of the two town divisions, the "red towns," and with the latter the opposing division or "white towns." This merely means that the red clans and red towns had official charge of matters concerned with war, not that they alone went to war. The chiefs (mikos) and second men (henihas) who occupied the principal civil positions were in some measure hereditarily determined since they were selected from definite clans, but war leaders seem to have been chosen on the basis of their demonstrated ability. The henihas, of whom mention has just been made, were either of the Wind clan or of some other white clan, and the mikos were oftener taken from white clans than from red ones. This was probably the rule in white towns. We also know that white towns were cities of refuge for enemies, and for murderers who had escaped from another settlement, though in the latter case the refuge was not necessarily a permanent one.

The fatal defect in the Creek organization as an instrument for preserving peace was the fact that social advancement depended largely on honors obtained in actions against an enemy. Success in hunting, in securing eagle feathers, in oratory and in another way to be mentioned shortly helped a man to rise in the esteem of his fellow citizens, but these were ineffective apart from war actions. It is not to be understood that what we here call war bore much resemblance to the institution with which white people are familiar. Rarely, and only incidentally, was a tribe destroyed or seriously injured in the course of such wars. They consisted merely of marauding expeditions by volunteer parties, which depended upon secrecy and surprise, were satisfied with a scalp or two, were quickly turned back by exposure or by an unfavorable omen and were considered failures if the lives of two or three men had been lost. The motivation of the whole system comes out clearly in the statement that an unsuccessful war party is known to have murdered members of their own tribe caught at some point remote from any settlement. The principal and perennial excuse for them—for war always demands such—was revenge for a past injury, though the Indian, like ourselves, simply conceived of it as "getting even." But of course neither side ever felt that it had attained this patriotic state of equilibrium and, as the powerful social impulse already mentioned never slept, peace was sporadic and rarely lasted long except where a tribe was admitted into the confederate body. Since this was not likely to happen in the case of large neighboring tribes like the Choctaw and Cherokee, war became increasingly bitter. Immediately after white contact it grew worse owing to the slave raiding expeditions instigated by the English colonists and entanglement in the mutual rivalries of the English, French and Spaniards. After American dominance had been established, however, Indian warfare no longer received encouragement and soon came to an end, whereupon the Indian population began to increase, imported epidemics having in the meantime spent themselves. This much our Indian wards may be said to owe us, though whether it was sufficient compensation for smallpox, tuberculosis, trachoma and alcoholism may well be doubted.

The warfare of attrition of which I have just spoken and the ever-present cloud of danger under which life must be conducted may be set down as constituting the outstanding defects in ancient Creek life, but it made up for this in freedom from that other black cloud of civilization which goes under the name of unemployment. Food, clothing and shelter were not inextricably united with the thing which we call a "job," nor were they given as charity. They were as much assumed as fresh air, water and sunlight. In the

latitude of the old Creek country clothing occasioned little worry. The articles of clothing were extremely simple; the raw material for them easily obtained, and they were durable. For food and shelter a man might rely always upon his fellow clansmen or, in a strange town, upon whoever had taken him under his protection. If no one did so, although this rarely happened, he was at liberty to sleep in the town house where during the winter a fire burned all night. So highly was hospitality esteemed that violation of it was one of the most heinous of all offences. Adair tells us that the Chickasaw characterized an inhospitable act by saying "the buzzard is at home," and that the application of this term was much dreaded.

Of course this meant that the more successful food-gatherers helped take care of those who were less successful and it will excite the disapproval of many good Americans with inherited bank balances, apprehensive for the safety of those twin deities of the industrial pantheon "individual initiative and energy." But a great deal of misconception of the workings of aboriginal hospitality has arisen owing to the nonconformity of primitive customs and modern life. I remember the case of an old woman on one of our Western reservations who received a sum of money from the agent on the first day of each month, whereupon her family connections promptly came to live with her and helped her to go through with it in half the time which it should have covered. Cases of this kind are numerous and are used as arguments not only against aboriginal institutions but against "socialistic" or "communistic" institutions generally on the ground that under them sloth is placed at a premium and industry at a discount. And perhaps the collectivist is moved to defend early man by pointing to these institutions as examples of mutual helpfulness and brotherly feeling.

But when we study the workings of hospitality under truly primitive conditions we find its detractors and its apologists both in error. In the old Creek Confederation each household was practically a self-supporting economic unit. The women manufactured the pots, baskets and clothing, and furnished the plant foods, except for such labor as was bestowed by men on the common fields. In addition to this last-mentioned work, men constructed the houses, made mortars and pestles for crushing grain, canoes, hunting and fishing implements and ceremonial objects, and furnished most of the animal foods and the raw material for skin clothing. A rude and temporary division of labor also existed between houses when individuals with different aptitudes exchanged the fruits of their industry instead of making all sorts of things for themselves, but production was so closely adjusted to consumption that there was no surplus except occasionally in the supplies of food. This, however, was ordinarily sent to less fortunate neighbors or dispensed in feasts, or in some of the regular ceremonials, though special hunting excursions were often undertaken in preparation for the last. Supplies were always laid up in the storehouse of each family and here it was possible to hoard, but the person who did so was regarded with utter contempt and was the object of general sarcasm and ridicule, not because such a man was felt to be a menace to the community but because he was regarded as a fool who chose to act contrary to his own best interests. For, in the first place, the surplus which he enjoyed one season might next year be converted into a deficiency, and who would then come to his assistance? In other words, generosity in the handling of food was of the nature of family insurance. But even if a family contained several extraordinarily good hunters and might look forward to continuous plenty with more assurance than their neighbors, it

was stupid of them to hoard since, by doing so, they not only attracted the ill will of the community but, unless they could make up for the defect by striking successes in war, they cut themselves off from those commanding positions in the tribe to which they might otherwise aspire. Attainment of leadership by "feeding the town" in time of want is the theme and moral of story after story repeated among Indians of the north Pacific coast. The agricultural life of the Creeks took away in some measure the importance and the peculiar opportunities of the hunter but they were still considerable and were probably greater before white contact. In short, in Creek society the distribution of surplus food was not merely ethical but for the interest of the owners of the surplus. Refusal to share it threatened their own future security and prevented them from advancing in the social scale—unless, of course, they could compensate by military exploits. It is significant that, along with our wide-spread popular recognition of Indian hospitality and generosity, we have preserved in the expression "Indian giver" a feeling that there was a string to all this, as was indeed the case.

But while a study of the economic and social system of the Creeks serves to destroy the myth that Indians were people of peculiar virtue, the system itself contains suggestions for the conduct of our own society that are not without value. It disproves at once the repeated assertion that a society that systematically feeds all its members can not be made to function. Creek society depended, and our own depends, on a pull and a push to make them operate. The pull upon which we rely is acquisitiveness and our push is starvation, while the pull of the Creeks was social position and popular esteem, and their push contempt and ridicule. Sociologists and political experts will do well to remember that this is no one's theory but the case of a working society. If we would approximate to it we must not only take government out of business but take money making out of it also.

From our review of the Creek Confederacy it appears that their manner of supporting life determined the nature of their organization only in its broadest outlines. In preserving the internal coherence of the state the most important single element was real and fictional consanguinity and affinity, but various tribes had been drawn into a supertribe by a special device involving the association of two sets of towns concerned with war and peace respectively with any of which outside units might become associated. Its major defect was in making war honors the principal stepping-stone to social advancement, so that the peace-promoting tendencies of the body taken as a whole were constantly nullified by the ambition of every male member of it. Alongside of this there existed a beneficent tendency to give social recognition to men who succored the community in time of want, but its good effect was destroyed by the emphasis placed upon man killing. However, in spite of the blight which the latter institution exercised, the well-being of every member of the state was its main concern, and all were fed, clothed and sheltered, the motive relied upon being common desire for insurance against unpredictable events, social esteem for the able and fear of ridicule for the sluggards.

THE PROGRESS OF SCIENCE

THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

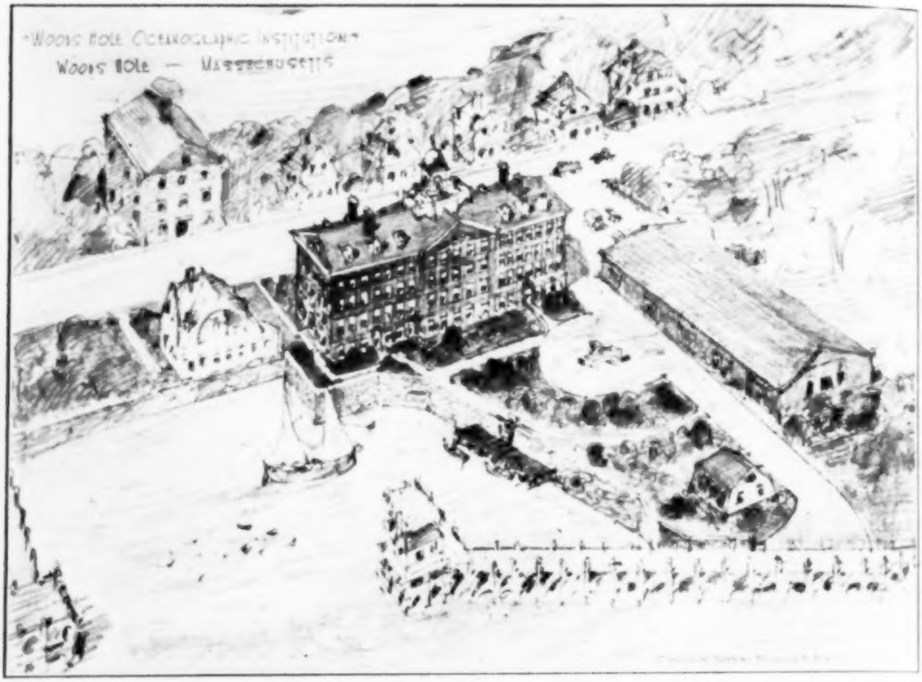
In February of this year, upon the recommendation of the National Academy of Sciences that "the establishment and endowment of an Atlantic oceanographic institute should be realized at the earliest possible moment," the Rockefeller Foundation granted $1,000,000 to finance buildings and equipment, and $1,000,000 as a permanent endowment fund. Later it agreed also to give $50,000 a year over a period of ten years to form a special operating fund. Dr. Henry B. Bigelow, research curator in zoology at the Museum of Comparative Zoology of Harvard University, was appointed director.

The purpose of the new institution, as its name implies, is to carry on and to encourage the study of the sea in the broadest sense. Like the Marine Biological Laboratory, it is an independent organization, but similarly assured of informal association with other educational and research institutions through the personnel of its trustees. The initial board is as follows: Dr. Thomas Barbour, Dr. Henry B. Bigelow (director), Dr. William Bowie, Dr. E. G. Conklin, Mr. Newcomb Carlton, Dr. Benjamin M. Duggar, Dr. Frank R. Lillie (president), Dr. John C. Merriam, Mr. Seward D. Prosser, Mr. Lawranson Riggs, Jr. (treasurer), Mr. Elihu Root, Jr., Dr. Harlow Shapley, Dr. T. Wayland Vaughan. The by-laws provide for an increase in the number of trustees up to twenty-four.

The choice of Woods Hole as the site for the headquarters of the new institution was reached only after a careful consideration of other possible situations along the Atlantic Coast of North America. The final decision was based on the combined advantage of close proximity to two world-famed laboratories of marine biology, on the one hand, and, on the other, on the exceptional opportunity for illustrative inves-

THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

THE BUILDING IS NOW UNDER CONSTRUCTION AND WILL BE COMPLETED IN THE SPRING OF 1931.



THE OCEANOGRAPHIC INSTITUTION AS IT WILL APPEAR FROM THE HARBOR

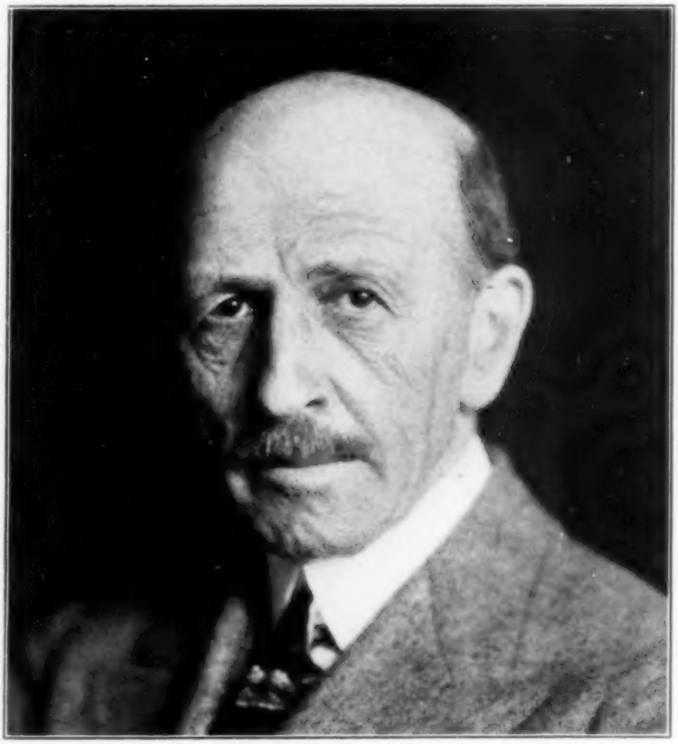
tigations that is offered by the neighboring waters.

The first of these inducements needs no explanation. The second depends in part upon the ease with which the transition from inshore to offshore waters can be reached from Woods Hole, on the abruptness of that transition and on proximity to the continental slope, and abyss. At the same time the Gulf of Maine, close at hand, with its tributaries, offers a more promising field for intensive investigations into the interaction between the physical-chemical and the biologic aspects of oceanography than any other sector of comparable extent along the coast of America.

The principal instrument of research will be the vessel which is as much a part of an oceanographic institution as a telescope is of an astronomical observatory. In fact, the whole institution centers around this boat which is to be the most modern of oceanographic vessels. Therefore a large sum of money is being spent on a floating laboratory. The plans for it have been completed and the contract for the work has been let. The ship which is being built in Copenhagen is 142 ft. long over all and 105 ft. at the water line; and its displacement will be about 380 tons. The vessel is to be a two-master with ketch rigging. An auxiliary Diesel engine will make it possible to cruise without sails, over a radius of several thousand miles. The vessel will contain two general laboratories, a chart room and about nine staterooms and the quarters for the crew of about thirteen, and a mess room. The Diesel engines run on crude oil, and there will be no gasoline on the boat. A catastrophe such as occurred in the case of the ill-fated *Carnegie* can not take place. The ship will be fully equipped with all the instruments used in oceanographic service. A drum with about five or six thousand fathoms of steel cable will be provided for dredging.

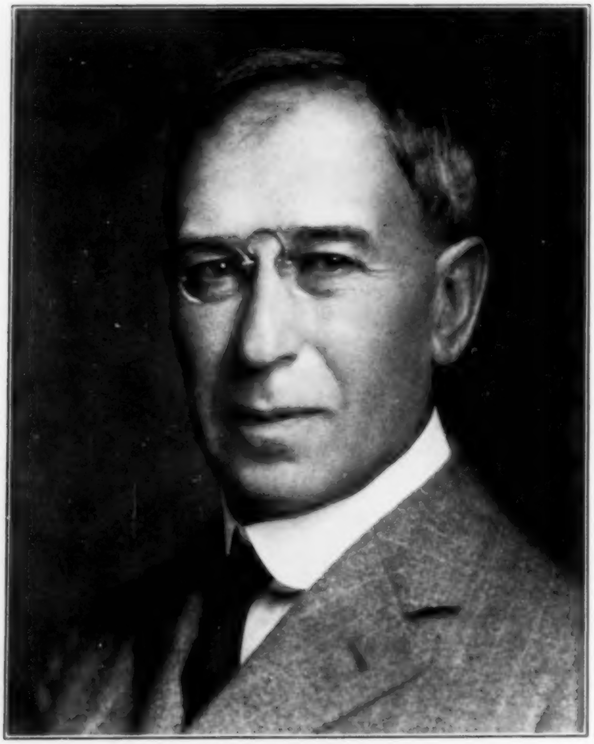
THE EIGHTIETH MEETING OF THE AMERICAN CHEMICAL SOCIETY

CINCINNATI, Ohio, was the science capital of the nation during the week of September 8, or at any rate the chemical capital, when some 2,000 chemists assembled for the eightieth meeting of the American Chemical Society. Convening under eighteen broad subdivisions of chemistry more than four hundred titles appeared on the program. Several symposia of significance were scheduled. One of these on industrial fermentation stressed the various phases of the employment of micro-organisms in chemical processes. Another symposium held jointly by the division of industrial and engineering chemistry, gas and fuel chemistry, and petroleum chemistry, was on industrial high pressure reactions, a subject of immediate industrial and research importance publicized extensively of late because of the success met by those working in the field of petroleum hydrogenation. The division of fertilizer chemistry presented a group of papers on the action of ammonium citrate on superphosphates, a topic of importance to those concerned with soil fertility and plant foods. Still another symposium was held by the division of medicinal chemistry



DR. WILLIAM McPHERSON

PRESIDENT OF THE AMERICAN CHEMICAL SOCIETY, WHO HAS BEEN A MEMBER OF THE STAFF OF OHIO STATE UNIVERSITY SINCE 1893 AND DEAN OF THE GRADUATE SCHOOL SINCE 1911. WHILE HIS PRINCIPAL INTERESTS HAVE BEEN IN CHEMICAL EDUCATION, HE HAS CARRIED ON RESEARCH ON THE HYDROXYAZO COMPOUNDS AND ON THE CONSTITUTION OF MANY ORGANIC COMPOUNDS, AND HAS BEEN ACTIVE IN THE ADVANCEMENT OF CHEMICAL EDUCATION.



DR. MOSES GOMBERG

PRESIDENT-ELECT OF THE AMERICAN CHEMICAL SOCIETY WHO WILL, ACCORDING TO THE PROCEDURE OF THE SOCIETY, BECOME ITS PRESIDENT FOR ONE YEAR, BEGINNING ON JANUARY 1, 1931. PROFESSOR GOMBERG IS THE CHAIRMAN OF THE DEPARTMENT OF CHEMISTRY AT THE UNIVERSITY OF MICHIGAN AND IS INTERNATIONALLY KNOWN FOR HIS WORK ON TRIVALENT CARBON AND FREE RADICALS, THOUGH THIS REPRESENTS BUT A PORTION OF HIS FUNDAMENTAL RESEARCH.

where endocrines was the subject. The qualifications of chemistry teachers resulted in active discussion in the division of chemical education, and non-aqueous solutions were of equal interest to research workers in the division of physical and inorganic chemistry. These symposia represented but a small fraction of the extensive program compiled with care by each of the divisions, and comprising topics of such interest that the leaders in chemistry attended in large numbers both to hear and to discuss.

There were divisional meetings on Wednesday and Thursday mornings, followed by luncheons at the University of Cincinnati. The president's address by Professor William McPherson, "Chemistry and Education," was given on Wednesday at 8:30 in the Emery Auditorium, following which there was a musical program.

On the afternoon of Thursday an inspection trip was made to the Cincinnati Water Works and there was a drive around the city in automobiles, starting from the university immediately after luncheon.

In the business sessions proposals for certain reorganization, the election of editors and the selection of further meeting places were considered. The eighty-first meeting of the society will be held in the spring of 1931 at Indianapolis, Indiana.—H. E. H.

BRONZE MEMORIAL PLAQUE, PICTURING MR. AND MRS. THOMAS A. EDISON, UNVEILED AT FORT MYERS, FLORIDA, IN CELEBRATION OF MR. EDISON'S EIGHTY-THIRD BIRTHDAY

DR. IRVING LANGMUIR AND DR. A. W. HULL WITH THE THYRATRON POWER TUBE

THE THYRATRON TUBE AND ITS POSSIBILITIES

From a series of original investigations of electron discharges in gases which Dr. Irving Langmuir carried out in 1914 in the research laboratory of the General Electric Company has come the thyratron tube, one of the most recent additions to the tube family. It has inherent advantages as a means of controlling electric power, and has begun to be used most effectively in this manner in such unique applications as the system of operating the stage lighting of the Chicago Civic Opera House from in front of the footlights, and the spectacular method of decorating with light the walls and ceilings of rooms, known as colorama.

But it is believed that the possibilities of the thyratron tube are not confined to the function of control. The men who have been responsible for its creation and development believe it may also become the means at some future time of accomplishing power transmission under more advantageous electrical conditions than those at present prevailing. This idea is based on the expectation that the thyratron tube may make it possible to transmit electrical energy over relatively long distances by means of direct current instead of alternating current.

Seeking to develop this proposition, an experimental miniature transmission line has been set up in the General Electric Research Laboratory and equipped with thyratron tubes. The artificial transmission line itself was represented by a copper bar about seven or eight feet in length. Electrical conditions were imposed in the matter of ohmic resistance which made this line equivalent to 400 miles of transmission conductor in a commercial system. As the longest commercial system now in existence is 250 miles in length, this experimental line, in its electrical characteristics, was more than 50 per cent. beyond present practice.

At the sending end of the line was installed a bank of thyratron tubes functioning as rectifiers, to convert alternating current into direct current for transmission purposes. At the receiving end of the line were installed other thyratron tubes which functioned in pairs as inverters. They inverted, or changed back, the direct current into alternating current. The source of current-supply for the experimental system was a bank of transformers which furnished alternating current at 15,000 volts.

When this interesting experiment was tried it was found that transmission of the power was accomplished without difficulty, and that the thyratrons, operating at one end as rectifiers and at the other end as inverters, handled successfully the current at 15,000 volts. At the receiving end the tubes delivered the energy to transformers, which reduced the pressure to the voltage of the working circuits in the laboratory shop, and through these circuits it was put to work in motors, just as is done in every-day practice everywhere.

As a further demonstration, the experiment was later repeated with the addition of a double-conversion process at the receiving end of the experimental line. After having been inverted and sent through "step-down" transformers, the current was passed through a motor-generator set and reconverted again into direct current at working voltages. Thence it was supplied to shop circuits which required direct current for regular work in direct-current motors.

The experiment was regarded as significant of what may be in store at some future period in electrical engineering developments. It is quite possible from

the present trend as revealed by this experiment that within the next decade —precisely how soon laboratory men do not care to speculate—direct-current transmission on a scale comparable with or at least approaching the present practice with alternating current will go into commercial usage.

Not since the earliest days of commercial application of electricity has direct-current transmission been considered practicable. In the electrical beginning of things, when arc lights first came into use, followed a few years later by Edison's incandescent lamp, almost all transmission in commercial systems was by direct current. That was fifty years ago, before the era of wide-spread electrical networks which serve an overwhelming majority of the nation's population. The arc-lamp systems operated on the series circuit and started in 1879 and 1880 with pressures of 2,000 volts, although in more recent times they have gone as high as 8,000 volts. The incandescent system utilized the multiple circuit, and transmission was at the low pressures of 110 or 220 volts. These represent two methods of transmitting economically by direct current, but their disadvantages would be so pronounced if employed under present-day conditions that the development of the transformer and the alternating-current systems that came in shortly before 1890 was little less than the salvation of electrical practice at that period. If transmission by direct current at high voltages can be accomplished, with the aid of the thyratron tube, the benefits both electrically and economically will be decidedly noteworthy.

The thyratron tube has been fifteen years in reaching its present state of development as a perfected and effective control device, with latent possibilities in transmission mentioned above. After Dr. Langmuir had conceived the idea of making use of the characteristics displayed by electron discharges in gases for controlling an electric arc by means of a grid, Toulon, in France, experimented in 1922 with Dr. Langmuir's process and devised an improvement on his method. Later, Dr. Langmuir and his assistants made other improvements. About 1926 Dr. Langmuir envisioned the broad practical possibilities of the principle, and thereafter Dr. A. W. Hull, in the same laboratory, developed the tube to its present status, making its commercial use in controlling power supply a reality. The tube, of the three-electrode type, differs from the familiar pliotron tube in being an arc rectifier in which a power arc is controlled electrostatically by the grid. In its control function it will economically handle relatively large amounts of electric power.